Enhancing the connectivity of Mobile Ad-hoc Networks by considering the Power, mobility, and activity of nodes.

Adwan Yasin[1], Salah Jabareen[2] and Iyas Al suqi[3]

**[1] Computer Science Department, Arab American University
Jenin, Palestine**

**[2] Computer Information Technology Department, Arab American University
Jenin, Palestine**

**[3] Computer System Engineering Department, Arab American University
Jenin, Palestine**

Abstract

Finding the best routing path in the Mobile Ad-hoc Networks (MANETs) is a very critical issue when designing MANET protocols, since many conditions affects the topology of the network, one critical condition is nodes power; it affects the node availability and network connectivity, so that the power of overall nodes should be used wisely to keep the topology stable and durable as far as possible. Another condition is the node mobility as nodes of MANET are mobile for all the time, the third condition is the node itself where the node operational time is considered to be a new factor. In our work we propose a new method for finding the best routing path based on these three factors.

Keywords: *MANET, power consumption, mobility, operational time, connectivity.*

1. Introduction

The invention of MANET [1], [13] has led to a lot of research ideas, MANET consists of mobile battery powered nodes, with no fixed infrastructure and hence each node operates as sender, receiver or router that forwards messages to other nodes. Such situations needs well defined protocols to deal with this type of network topology and able to build routing tables efficiently. The problem in MANET is that it needs rapid reconstruction of the routing tables because of the unpredicted change of the topology; those changes occurs because of several factors, the limited power of the nodes, mobility, limited heterogeneous capabilities of the nodes and unpredicted behavior[14].

Many protocols has been developed for MANETs, one of the most used protocols is AODV [2], this protocol asks for a route based on the demand and keeps silent until a node requests a route to send messages to a destination. This protocol leads to the invention of enhanced protocols to deal with power and mobility of the nodes, some of those protocols are, LEAR-AODV [3], PAR-AODV [4] and LPR-AODV [5] that uses power constraint as the main factor in building the routes. Some other protocols takes the mobility of the node into calculations where the mobility could give us a predicted time for a link to stay alive. The other factor reflects the operational time of the node, since MANET consists of many different types of nodes, each with different behavior, for example; the laptop device could be off in unpredicted behavior and different than phones which may stay ON for longer times. Here we aim to build a history of node behavior so we can predict the node activity for the next specific period of time.

The best way to find the optimal route is to balance those three factors and get least cost and long living route. In this paper we propose a new algorithm to balance all the three factors to ensure that we are using the optimal route of all available routes from source to destination.

2. Lowest Cost, Long Living and Stable Routes

To find the link with minimum power consumption and higher power level; this parameter depends on the power level of the node itself so that we can choose the node with higher battery level, also calculating the power to consume when transmitting or receiving or hearing information. This parameter affects directly the network connectivity lifetime and hence the network topology change. We aim by applying this parameter to choose best link that will consume lower power and keep nodes alive as long as possible by using only nodes with higher residual power. When choosing a routing path it is important to know how long it will be available to use; which means the network will predict that the desired link will serve the process of transmitting or not and how long I can keep this link in the routing table to use for further transmitting for a desired destination.

This operation could be done simply by predicting the mobility of node. If I know the mobility direction of the neighbor nodes I can directly decide for how long each node will stay in my range and hence to know the predicted time for the node to be available to be used. Another factor is the operation time, This issue related directly to the node itself, when deciding the link based on power and mobility, it is good to think about the node availability history; this parameter depends somehow on the node participating readiness, in other words, the node could be always ON or it could be for example 50% of its time OFF, let's say a user of a node keeps turning Wi-Fi on or off in a sudden or unpredicted periods. Such situations can be predicted to decide whether to use a node or not based on its history; we can predict that a node will stay up for the next specific time so I can calculate the stability of the link by predicting the readiness behavior of the nodes.

3. Related Work

Some other papers referred to the concept of finding the best route using power metric as the main and only factor of selecting the best route; Sharma and Bhadauria in [9] used an agent based technique to find the route; the agent starts checking all available paths and then decides which nodes to choose based on its current state whether it is in listening or non-listening modes, the state of listening or non-listening is decided based on the power level of the node. The chosen path is selected based on the cost (C) of the path and the congestion metric (TCM) for all nodes participating this path. The power metric takes the remaining battery capacity and the drain rate of node when transmitting data. The Total Congestion Metric (TCM) can be estimated from the obtained queue length and the channel contention. This approach works fine but it only consider the power metric.
Another assumptions takes the node mobility into calculation in addition to power; like in [10] they consider node mobility and battery power ratio factors for stability of nodes. Link time between two nodes depends on both factors. Selecting the routes between sources to multicast group depends on stability of nodes corresponding to neighbor. GPS system is used for finding the geographical information like coordinates of the nodes. Simulation Results shows that SLBMR perform better in term of packet delivery ratio and control packet overhead. This work well but the GPS system consumes power of the nodes.
A. Abdel Fattah in [11] shows a different scheme for selecting nodes participating the link between source and destination, he used the power factor and the ability of the node and finally the connectivity of the node; his scheme suggests to divide the network into interoperable domains which balances the power consumptions; the process of dividing the domains depends on the connectivity and ability of the adjacent nodes. This scheme does not take mobility of the node into consideration which is a very important factor.

The authors in [12] suggest a new method based on probability of the node selection method which considers the energy distance vector. This factor helps to select the best next hop node for optimizing the energy efficiency of the network. The scheme also considers the residual energy of the nodes as a fraction rather than the absolute energy levels. Based on this scheme of selecting nodes with sufficient residual energy, an energy aware routing protocol for MANETs is proposed.
The authors in [15] suggested a model for calculating the energy spent at a node due to a flow in the network, and include the transmission and reception costs if the node belongs to a flow, and reception costs if it is near a flow. Such mechanism can handle several flows power aware routing and hence provide a mechanism for calculating power cost, and provides calculation for flows requires QoS. This mechanism also guarantee that the route selected does not die midway. The problem in such mechanism is that it works in ideal conditions where no interference, also it does not take mobility or node capabilities into consideration

4. Power Efficient Routing

Energy consumption is the most critical factor in designing the routing protocol for MANETs, in our work we will use a well-built mechanisms to calculate the power consumption because of transmission, selecting the next hop node will depend on the distance of that node, because transmission power depends on the node distance, we will use mechanisms for modifying power transmission based on distance between nodes, distance could be calculated using Receiving Signal Strength Indicator (RSSI).

In the parameter of power we will take also the residual power of the node into consideration simply to keep all nodes up as long as possible and make them useful for longer time, it is done by simply choosing nodes with higher battery level.

4.1 Measuring distance using RSSI value

The Received Signal Strength Indicator (RSSI) describes the relation between transmitted powers and received powers in the following equation [6]:

$$p_r = p_t \times \left(\frac{1}{d}\right)^n \quad (1)$$

Where p_r is receiving power, p_t is the transmitted power; d is the distance between sender and receiver node and n is the transmission factor whose value depends on the propagation environment.

Now we need to show the relation between RSSI and distance, for calculating the received power based on this model, we first calculate the received power at a reference distance using the Friis formula (given in Eq. (1)). Then, we incorporate the effect of path loss exponent and shadowing parameters [7].

$$RSSI = -(10 \times \log_{10}(d_{i,j}) - A) \tag{2}$$

The theoretical distance between nodes is given by:

$$d_{ij} = 10^{\frac{RSSI - A}{-10*n}} \tag{3}$$

Where:

d_{ij}: distance from node I to node j.

RSSI: receiving signal strength indicator.

A: is received power from reference distance which is 1 meter

n: is the transmission factor whose value depends on the propagation environment.

By using Eq. (3) each node knows exactly the distance to all its neighbors and hence decides which node to use as the next hop route.

Another important issue is the power consumed for transmitting some amount of data over Wi-Fi for nodes, this issue related to the operation being done and the mode of operation; we can derive the amount of power consumed for transmitting an amount of data during a period of time (t) is presented as follows [8]:

$$E(t) = \sum_j E_j(t_j) + \sum_j \sum_k E_{j,k} \times C_{j,k}(t) \tag{4}$$

Where $E(t)$ is the total energy consumed by the hardware component over the duration t, $t = P_j\ t_j$, t_j is the duration spent in power state j and $E_j(t_j)$ is the energy spent during t_j. Assuming that P_j, the rate of energy consumption in power state j, is constant during t_j, $E_j(t_j)$ can be calculated as the product of t_j and P_j . $E_{j,k}$ is the overhead caused by the transition from power state j to k, while $C_{j,k}(t)$ shows how many times this transition has occurred during t.

Now we can simply calculate the remaining power of each node after transmitting the desired data and know who costly will be the process of transmitting the data. The calculated remaining power of the node after transmission denoted as RBP will be calculated as follows:

$$RBP = \frac{AVLBP - E(t)}{MPB} \tag{5}$$

Where:

RBP: remaining battery power.

AVLBP: available battery power.

E(t): the total energy consumed by the hardware component over the duration t.

MPB: maximum battery power.

The optimal node should be chosen as an intermediate routing node will be the one with higher RBP after calculating the amount of power will be consumed as described in Eq. (4).

5. Node Operational Time Calculation

Here we consider the activity history of each node. We assume that each node will record its readiness history, in other words the node will record for how long it will be available to be used. The node availability time is the average of all operational time over the entire live-time of the node. Figure (1) shows a node operational time history over a period of time (t), the node keep changing mode from operational and non-operational modes, we can calculate the average time that node was in operational mode.

The average time of operational modes where the node was active and ready to receive and participate in the routing process.

$$AOT(t_x) = \frac{\sum OP}{NO.Operatinal\,Periods} \tag{6}$$

Where:

AOT(tx): average operational time at specific time t_x.

Now the *AOT* is the time we predict that the node will stay operational at any time, to calculate the remaining predicted time at the operational time t_x:

$$PROT(t_x) = AOT(t_x) - OP(t_x) \tag{7}$$

Where:

PROT (t_x): Predicted Remaining Operational Time at time t_x.

Once a route request arrives to a node at time t_x, the node could estimate for how long it will be operational by using Eq. (6) and Eq. (7).

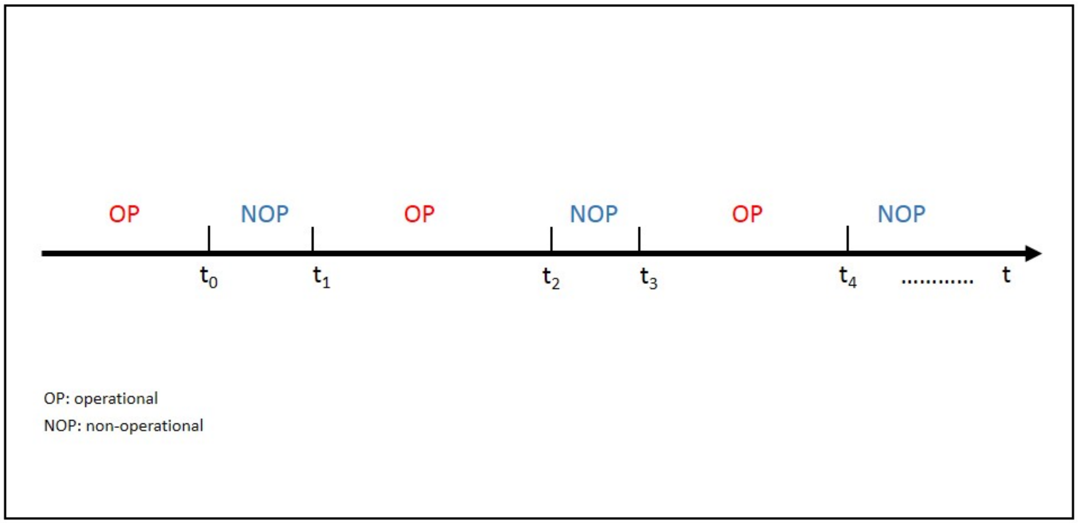


Fig. 1. Example of node operational time over life-time

6. Node Mobility Calculation

Another critical factor that affects the route selection algorithm is the node mobility. It is better to select a node that will serve the process of routing for longer time and will not go outside the transmission range until the process completes. We can predict the time for a node to be in the range by calculating its speed and direction of movement. The speed and direction could be calculated by applying RSSI measurement for distance between two nodes (*i,j*) from Eq. (3), we assume that sending several signal to measure distance over a specific period of time will give an estimated information about node movement and speed. For example, if we send several RSSI check and calculated the distances between *i* and *j* we can retrieve the speed and whether the node j moves closer or moves away from node *i*. figure (2) shows an example of two mobile nodes *i,j*.

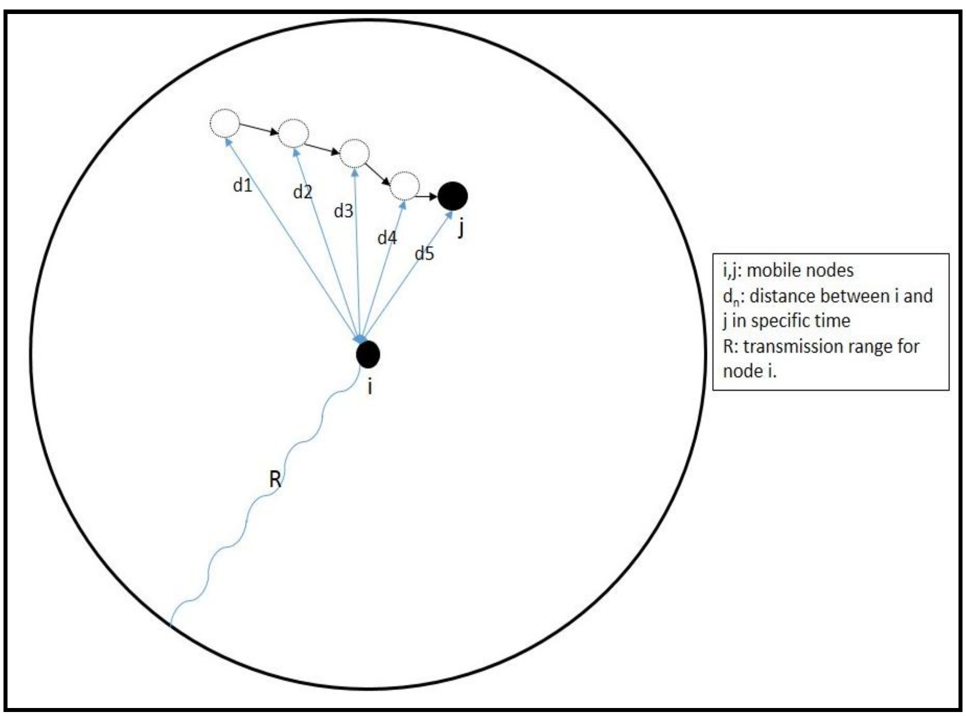


Fig. 2. Example of tw o mobile nodes

From figure (2), node i can calculate the speed of node j by sending several RSSI request and measure the distances over a specific period of time t; to check the speed and direction of movement as follows:

$$NS = \frac{\sum_{k}^{n} \frac{|d_{k+1} - d_k|}{t_k}}{n} \quad (8)$$

Eq. (8) shows the average node speed (NS) of node j in reference to node i, where $|d_{(k+1)} - d_k|$ is the distance that node j moves after each successive measure k and t_k is the time between every successive measure, n is the number of times we check the distance between i and j.
Now, we need to check whether node j moves away from node i or moving toward node i; this could be calculated by the difference between d_n and d_1 ; if the difference is positive then the node is coming closer and if negative then the node moves away.

When the node moves away we predict that the node j will be out of range after $LBT(i,j)$ time as follows:

$$LBT(i,j) = \frac{R - d_n}{NS} \quad (9)$$

Where:
$LBT(i,j)$: the link breakage time between node i and node j.

The $LBT(i,j)$ shows the time that anode still be reachable based on its mobility and direction of movement; in other words the link between i and j will break after LBT time.

7. Scheme and Optimal Route Calculation

- The sending node S calculates the distance and mobility for all of its neighbors and sends a Route Request (RREQ) to all its neighbors holding those information.
- Each node receives a RREQ will also calculate the distance and mobility of neighbor nodes, holding those information into RREQ message with other node information.
- Every node receives a RREQ message will pass it to its neighbors holding the following information:
  - Its own RBP and its own $PROT$.
  - The distance to every neighbor node.
  - The mobility factor LBT to every neighbor.
- Those information reaches the Destination node S via RREQ messages from its neighbors.
- The Destination node will calculate the optimal route among the available routes received using the following:

For each route R the LBT is the lowest LBT for all links in that route from the source S to Destination D:

$$RLBT(S,D) = MIN(LBT(i,j)) \quad (11)$$

$RLBT(S,D)$: is the link breakage time from source S to destination D.

The route R has also other factor related to nodes themselves which is the PROT value; for each route R the RPROT is the minimum PROT for each node participating that route from source to destination:

$$RPROT(S,D) = MIN(PROT(i)) \quad (12)$$

Where:
$RPROT(S, D)$: the route predicted operational time for nodes participate a route R.

The last factor is the node RBP for all nodes in a Route R from source to destination which will also be the minimum among all nodes in a specific route; the equation will become as follows after adding the RBP:

$$RS(S,D) = MIN\big(RLBT(S,D), PROT(S,D)\big) \times MIN(RBP(S,D)) \quad (13)$$

Where:
RS: is the route stability.
$RBP(S, D)$: the remaining battery power for all nodes from source S to destination D.

The destination node will select the route that has the Maximum RS factor and sends a route reply RREP using that route to use for forwarding data to the destination:

$$OR = MAX(RS(S,D)) \quad (14)$$

Where OR is the Optimal Route.

8. Conclusion

Achieving sustainable connectivity is an ultimate goal during MANET construction. There are many factors that affect this issue, but the most important of them are power consumption, mobility and nodes availability. During the routing process it is important to choose best link that will consume lower power and keep nodes alive as long as possible by using the nodes with higher residual power. When choosing a routing path it is important to know how long it will be reachable and available by knowing the mobility direction and operational time history of each node. In this article we have considered these factors as they are changing over the time and directly affect the network topology in order to enhance networks lifetime connectivity.

References

[1] Charles E.Perkins, "Ad hoc Networking", Addison Wesley, 2001.

[2] C. Perkins, E. Royer, "Ad-hoc on-demand distance vector routing". Proc of. 2nd IEEE Workshop. Mobile Computing Systems and Applications (WMCSA 00), 1999, 90–100.

[3] S.-M. Senouci and M. Naimi, "New routing for balanced energy consumption in Mobile Ad Hoc networks", Proceedings of the 2nd ACM international workshop on Performance evaluation of wireless ad hoc, sensor, and ubiquitous networks, 2005.

[4] Kush, Ashwani; Phalguni, Gupta; and Ramkumar, Chauhan, "Power Aware Routing in Ad Hoc Networks", Transactions on Internet Research, Volume 1, No 2, ISSN 1820 – 4503, July 2005.

[5] M. Maleki, K. Dantu, and M. Pedram, "Lifetime Prediction Routing in Mobile Ad Hoc Networks," Proc. IEEE Wireless Comm. and Networking Conf., pp. 1185-1190, Mar. 2003.

[6] Zhang Jianwu, Zhang Lu "Research on Distance Measurement Based on RSSI of ZigBee" CCCM IEEE 2009.

[7] Neeraj Choudhary, Ajay K Sharma "Performance Evaluation of LR-WPAN for different Path-Loss Models" International Journal of Computer Applications (0975 – 8887) Volume 7– No.10, October 2010.

[8] Yu Xiao, Yong Cui, Petri Savolainen, Matti Siekkinen, An Wang, Liu Yang, Antti Yl¨a-J¨a¨ aski and Sasu Tarkoma "Modeling Energy Consumption of Data Transmission over Wi-Fi" Mobile Computing, IEEE Transactions on (Volume:PP , Issue: 99), ISSN : 1536-1233 , 19 April 2013.

[9] Vishnu Kumar Sharma, Dr. Sarita Singh Bhadauria "Congestion and Power Control Technique Based on Mobile Agent and Effect of Varying Rates in MANET", International Journal of Advancements in Computer Science and Information Technology [2250 – 2440] Vol. 01, No. 1, September, 2011.

[10] Kamal Kant, Lalit K. Awasthi, "Stable Link Based Multicast Routing Scheme for MANET" 2010 International Conference on Computational Intelligence and Communication Networks.

[11] Adwan AbdelFattah "An Efficient Scheme for MANET Domain Formation (ESMDF) " , (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 2, No. 9, 2011

[12] Jailani Kadir, Osman Ghazali, Mohamed Firdhous, and Suhaidi Hassan, "Node selection based on energy consumption in MANET", The 12th International Arab Conference on Information Technology (ACIT), 11th-14th December, 2011, Riyadh, Saudi Arabia.

[13] Subir Kumar Sarkar, T.G. Basavaraju, C. Puttamadappa "Ad Hoc Mobile Wireless Networks: Principles, Protocols and Applications" , Auerbach Publications – Taylor & Francis Group, 2008.

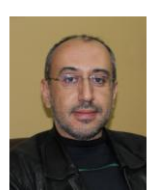
[14] Priyanka Goyal, Vinti Parmar, Rahul Rishi "MANET: Vulnerabilities, Challenges, Attacks, Application", IJCEM International Journal of Computational Engineering & Management, Vol. 11, January 2011 ISSN (Online): 2230-7893.

[15] Géraud Allard, Pascale Minet, Dang-Quan Nguyen, Nirisha Shrestha "Evaluation of the Energy Consumption in MANET" , ADHOC-NOW'06 Proceedings of the 5th international conference on Ad-Hoc, Mobile, and Wireless Networks Pages 170-183.

Authors:

Adwan Yasin PH.D Computer System Engineering /Computer security /Kiev National Technical University of Ukraine, 1996. Master degree in computer System Engineering- Donetsk Polytechnic institute, Ukraine, 1992. An associate professor currently Dean of the Engineering and Information Technology Faculty of the Arab American University of Jenin, Palestine. Previously he worked as Chair Person of Computer Science Department- AAUJ, Assistant professor of the computer Science Department -The Arab American University-Palestine. Assistant professor of the computer & Information System Department, Philadelphia University- Jordan. Assistant professor of the Computer science department, Zarka Private University- Jordan. He has many publications in the fields of computer networking and security in different international journals. His research interests Computer Security, Computer Architecture and Computer Networks.

Salah Jabareen Master student at the department of computer Science at Arab American University – Jenin, Palestine. Finished his BA in computer science field at the Arab American University in Palestine. He works as teacher assistant at the faculty of Engineering and Information Technology at Arab American University – Jenin, Palestine. His research interest include computer networks, artificial intelligence, computer architecture and security.



Iyas AL Suqi Master student at the department of computer Science at Arab American University – Jenin, Palestine. Finished his BA in Computer Engineering from Arab Academy For Science and Technology University in Egypt. He works as teacher assistant at the faculty of Engineering and Information Technology at Arab American University – Jenin, Palestine. His research interest include computer networks, artificial intelligence and distributed systems.