Performance Evaluation of Energy Efficient Routing Algorithm for Ad-hoc Network

Arijet Sarker, Nasrin Fatema, Bratati Roy Binti
Institute of Information Technology
Jahangirnagar University
Dhaka, Bangladesh
Email:{monmoysarker, nusrat1811, bintibintu}@gmail.com

M. S. Kaiser
Institute of Information Technology
Jahangirnagar University
Dhaka, Bangladesh
Email:mskaiser@juniv.edu

***Abstract*—In this paper, we have proposed a Neuro-Fuzzy (NF) based adaptive, energy efficient routing algorithm for a wireless ad-hoc network. It consists of self-organizing decentralized wireless nodes which does not rely on a pre-existing infrastructure. Each node participates in routing by forwarding data dynamically on the basis of network connectivity. Routing protocols for ad-hoc networks have to ensure reliable multi-hop communication. Routing of data is the major consumer of energy in the network, efficient routing protocols can reduce the energy consumption drastically. Thus reliable and energy efficient routing algorithm are the main concern of proposed routing algorithm. In this work, all nodes take routing decisions based on bit error rate (BER), end-to-end delay, doppler shift and battery life. The proposed algorithm is compared with the existing routing algorithms proposed in different literature. The performance analysis illustrates that the proposed algorithm outperform all the existing routing algorithm in worst case scenarios.**

***Keywords*—Ad-hoc,Energy efficiency,Neuro-Fuzzy based adaptive rouing, BER, Doppler Shift**

I. Introduction

Wireless ad-hoc network consist of a number of autonomous nodes spread over a geographical area. They communicate with each other via wireless link without any additional backbone infrastructure. These nodes are small, lightweight and portable. Every node is arranged with a transducer, a microcomputer, a transceiver and a power source. These nodes also have limited resources like battery life, storage, processing capabilities, bandwidth and transmission range [1]. If two nodes are not within a mutual transmission range, they communicate through their neighboring nodes which then exists within the range. Thus node selection is a critical issue and key challenge for network designer. Nodes can be selected based on neighbor nodes information like hop count, bandwidth, battery life, Doppler shift, Bit Error Rate (BER), queue length etc. All nodes in ad-hoc network have equal status and use same Service Set Identifier (SSID). There are a vast number of applications of ad-hoc network such as disaster relief, monitoring, data gathering, community mesh networks etc. There are many challenges of ad-hoc network such as medium access control, routing, topology control, energy efficient system design, deployment strategies in different development tools, route disconnection or link failure, high packet loss, end to end Transmission Control Protocol (TCP) performance degradation due to unpredictable change in network topology etc [2]. To overcome the challenges of ad hoc network many routing and transport approaches have been used. Routing means route between a particular source-destination pair. Routing can optimize several parameters such as hop count, route stability, energy consumption, power saving for nodes and routing overhead at the same time [3] [4] [5] [6] . Routing of data is the major consumer of energy in the network and due to the mobility of the nodes, reliable routing between source and destination is needed for successful packet transmission. So energy efficient and reliable routing algorithms are needed for successful packet transmission between source and destination. Routing protocol in ad hoc network should be scalable compare with network size and the number of nodes. Routing protocol provides a certain desired quality of service (QoS) with parameters such as bandwidth, delay, packet delivery ratio, throughput and also support real time traffic and discover loop-free routes. In this work, Neuro-Fuzzy (NF) based adaptive, energy efficient routing algorithm for ad hoc or wireless ad hoc network has been proposed. The main objective of our proposed algorithm is to design an energy efficient and reliable routing protocol. BER, Doppler Shift and Queue length/delay are the important parameters for reliability measurement. Energy consumption is also considered for achieving energy efficiency. According to the algorithm, a particular node will choose the shortest path from one or more incoming requests based on BER, Doppler Shift, Queue length/delay, Battery life and Reliability. In this work, performance evaluation of the proposed algorithm has also been done.

II. Related Works

With the revolutionary advancement in the field of wireless ad hoc network and its increasing application, proposing energy efficient and reliable routing algorithms is now main concern in the field ad hoc network research. Several routing protocols had been proposed in different research papers. Improving network efficiency and maximizing network lifetime were emphasized on a paper, where the proposed algorithm was worked well for low sensing and computational capabilities [7]. Lower cost, higher frequency and ultra high speed were considered in another paper, where the algorithm was worked well for less reliable and unprotected channel [8]. An algorithm on cross-layer, aggregate congestion and power consumption optimization was proposed in [9], which was efficient for low bandwidth and energy. An algorithm was proposed evaluating capacity, delay and mobility for handling the frequent changes in the network topology [10]. Considering Doppler shift and BER an algorithm was proposed which worked well for frequency distortion [11]. Efficient node discovery and End-To-End Delay Optimization was also focused in couple of papers [12] [13]. Stage and Smooth Design (SSD) was introduced in a paper evaluating Safeguarding Schedule Update.This algorithm worked well for link quality [14]. To save energy consumption at the same time as to keep the latency bounded an algorithm was proposed which worked well for a shorten range of time [15]. Considering energy cost, delay cost, location information and power control to balance the energy and delay cost for data gathering in sensor networks,an algorithm was proposed in [16].

III. System Model

In ad-hoc network, a node is able to accomplish processing, gathering information and communicate with other nodes in the network. Nodes gather and control information collected by other nodes. The access point is used to forward data from gateway node to server via internet. Figure 1 shows the considered scenario. In the proposed algorithm, considered parameters for the selection of the shortest path are BER, Doppler Shift, QueueLength/Delay, Battery Life and Reliabilty. BER is the total number of erroneous bits compared to the total number of transmitted bits. BER is expressed in percentage. Queue length/delay is the total time experienced for a packet to travel throughout a network from source to destination node and the waiting time to be processed by that destination node. Battery life is one of the vital concern in the design of energy efficient wireless ad hoc networks. It is a measure of battery performance. Doppler Shift is the change in frequency due to the displacement of a node. Reliability is the uniformity of results from a test. It determines the proportion of the fallacious test score.

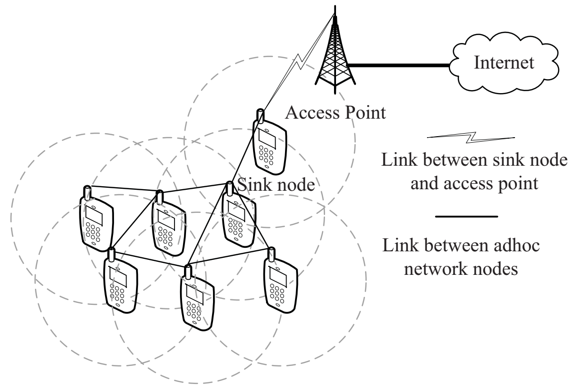

Fig. 1. System Model

IV. Proposed Routing Algorithm

In the proposed algorithm, main aims are to achieve reliable and energy efficient performance. The proposed algorithm is given below:

A. Procedure

- Step 1: Source node, denoted by S, broadcasts a hello message to all nearby nodes with parameters (S_{id}, D_{id}, ΔE, Δf and Γ), where S_{id} is the source identification number, D_{id} is the destination identification number, ΔE is the battery saving, Δf is the Doppler shift and Γ is the Reliability index.
- Step 2: The multicast message will be received by nearby nodes which has the link from that nodes. After receiving, one or multiple incoming request message will calculate the best link considering the parameters (BER, δ, ΔE, Δf and Γ), where δ is the Queue length/delay, from incoming hello message. This way source nodes select best link.
- Step 3: If a node recognizes its own id as destination id, it will finally calculate the shortest path as stated above. Shortest path link will be generated from the shortest path parameter sending by each node. Then the destination node will broadcast the acknowledgement message with parameters (S_{id}, D_{id}, Υ), where Υ are shortest path link.
- Step 4: When the source node will receive the acknowledgement message, it starts data communication using shortest path link. After receiving the actual message, destination node will again send acknowledgement message. The source node will continue to send messages using the same path till the source node will receive the acknowledgement message from destination node.
- Step 5: When the source node does not receive acknowledgement message, it will start from Step 1.

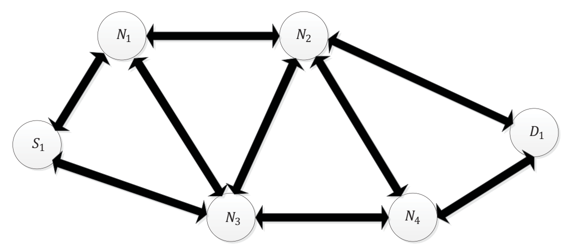

Fig. 2. Simplified Considering scenario

B. Example

In figure 2, Suppose source node S_1 wants to send message to destination node D_1. Here,N_1,N_2,N_3,N_4 are intermediate nodes. According to the proposed algorithm, following steps will be proceeded:

- Step 1: S_1 will broadcast a hello message to nearby nodes with parameter (S_{id}, D_{id}, ΔE, Δf and Γ).
- Step 2: Incoming message will be received by N_1 and N_3. Here, N_1 will calculate the (BER, δ, ΔE, Δf and Γ). As, N_1 receives only one incoming request, it has no comparison to make for best path. Then, N_1 will broadcast a request message to nearby nodes as stated in steps 1 with an additional parameter (S_1N_1). Here, S_1N_1 means shortest path for N_1. N_3 will also calculate shortest path considering all the parameters (BER, δ, ΔE, Δf and Γ) from two incoming request from S_1 and N_1. Then N_3 will broadcast a request

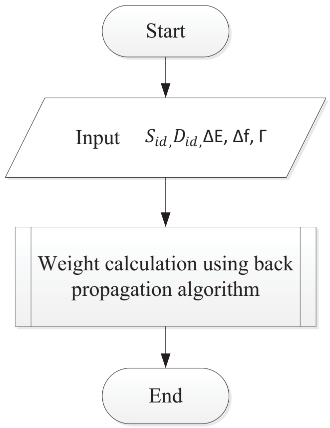

Fig. 4. Weight Calculation

message to nearby nodes as stated before with and additional parameter (S_1N_3). Here, S_1N_3 means shortest path for N_3. N_2 will receive request from N_1 and N_3. Suppose, the best path according to shortest path calculation is N_3N_2. So, it will broadcast the shortest path parameter as $S_1N_3N_2$.

- Step 3: Same process will be applied for N_4. Suppose,the shortest path $S_1N_3N_4$. Finally, D_1 will choose the shortest path from N_2 and N_4. Suppose, the best path from N_4. So, D_1 will generate the shortest path link $S_1N_3N_4D_1$ as the target id is D_1.
- Step 4: D_1 will broadcast the acknowledgement message with parameters [S_{id} ,D_{id}, shortest path link ($S_1N_3N_4D_1$)].
- Step 5 : When S_1 does not receive acknowledgement message, it will star again from step 1.

Figure: 3 and Figure 4 shows the flow chart of message transfer and route query and weight calculation of path using considered parameters respectively.

C. ANFIS Model

IF x_1 is A_1 AND x_2 is B_1 AND x_3 is C_1 AND x_4 is D_1 AND x_5 is E_1, THEN

$$f_1 = p_1x_1 + q_1x_2 + r_1x_3 + s_1x_4 + t_1x_5 + u_1 \tag{1}$$

IF x_1 is A_2 AND x_2 is B_2 AND x_3 is C_2 AND x_4 is D_2 AND x_5 is E_2, THEN

$$f_2 = p_2x_1 + q_2x_2 + r_2x_3 + s_2x_4 + t_2x_5 + u_2 \tag{2}$$

IF x_1 is A_3 AND x_2 is B_3 AND x_3 is C_3 AND x_4 is D_3 AND x_5 is E_3, THEN

$$f_3 = p_3x_1 + q_3x_2 + r_3x_3 + s_3x_4 + t_3x_5 + u_3 \tag{3}$$

Membership value for premise parameter is calculated in layer 1 where node output of layer 1 is membership value of input. Output $O_{1,i}$ for node $i = 1, 2, 3$ is

$$O_{1,i} = \mu_{A_i}(x_1) \tag{4}$$

Output $O_{1,i}$ for node $i = 4, 5, 6$ is

$$O_{1,i} = \mu_{B_{i-3}}(x_2) \tag{5}$$

thus continued to node 15 using same formula. Here, A is a linguistic label (small,medium,large)

$$\mu_A(x_1) = \frac{1}{1 + |\frac{x_1 - c_i}{a_i}|^{2b}} \tag{6}$$

Firing strength of rule is indicated in layer 2, where node output is the firing strength of rule.

$$O_{2,i} = w_i = \mu_{A_i}(x_1)\mu_{B_i}(x_2)\mu_{C_i}(x_3)\mu_{D_i}(x_4)\mu_{E_i}(x_5) \tag{7}$$

(for $i = 1, 2, 3$) Normalize firing strength is calculated in layer 3, where node output is normalized firing strength.

$$O_{3,i} = \overline{w_i} = \frac{w_i}{w_1 + w_2 + w_3} \tag{8}$$

(for $i = 1, 2, 3$) Node output of layer 4 is evaluation of right hand side polynomials, where consequence parameters $[p_i, q_i, r_i, s_i, t_i]$ are considerd.

$$O_{4,i} = \overline{w_i}f_i = \overline{w_i}(p_ix_1 + q_ix_2 + r_ix_3 + s_ix_4 + t_ix_5 + u_i) \tag{9}$$

Overall output is calculated in layer 5, where node output is weighted evaluation of RHS polynomials.

$$O_{5,1} = \sum_i \overline{w_i}f_i = \frac{\sum_i \overline{w_i}f_i}{\sum_i \overline{w_i}} \tag{10}$$

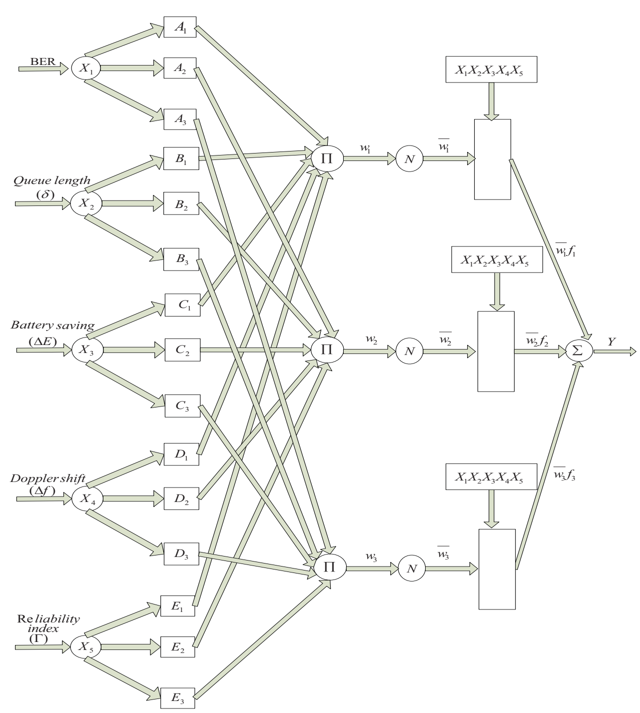

Fig. 5. ANFIS Architecture

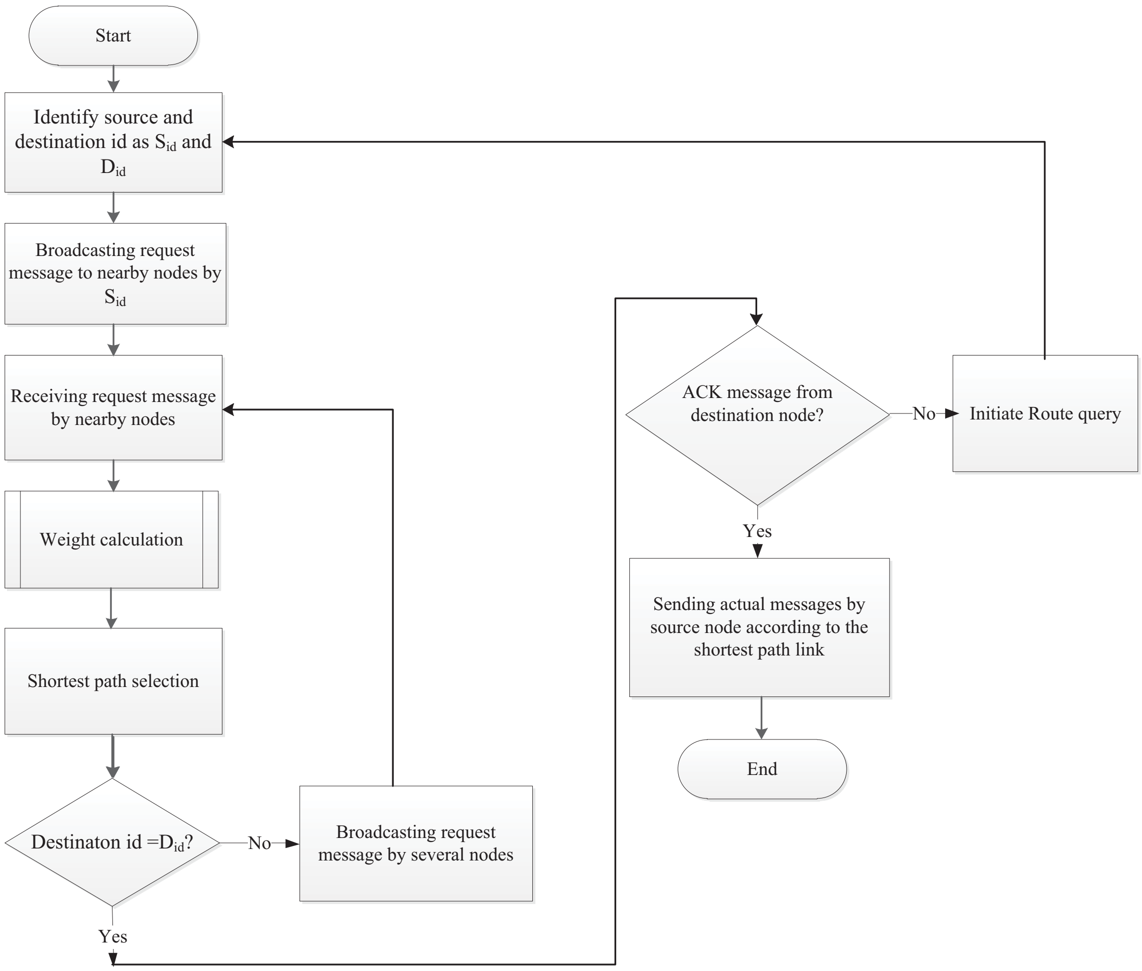

Fig. 3. Route query and message transfer

V. Numerical Analysis

Selection of parameters are important in routing algorithms. Parametrers defines the way of shortest path calculation. In this section, comparison with proposed algorithm and other existing ad hoc routing protocols have been analized. For reliable routing energy consumption is an important factor. Changes in energy consumption with the inflaton of nodes are also described.

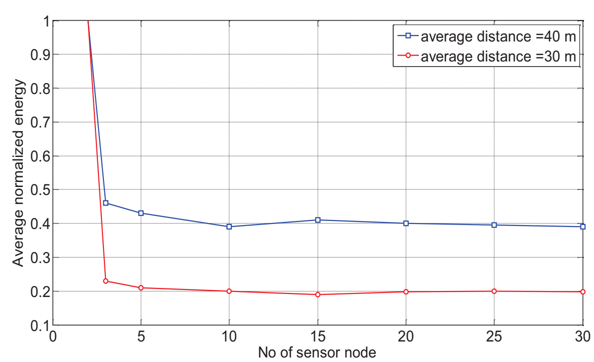

Fig. 6. Normalized energy consumption vs. the number of sensor nodes for different values of average distance between nodes

A. Energy Consumption

Normalized energy is the ratio of transmission based on cooperation to no cooperation. Figure 6 shows the effect of number of sensor nodes for different average distances on the normalized energy results. This is due to a reduction in the energy needed on the cooperative node for shorter distance.

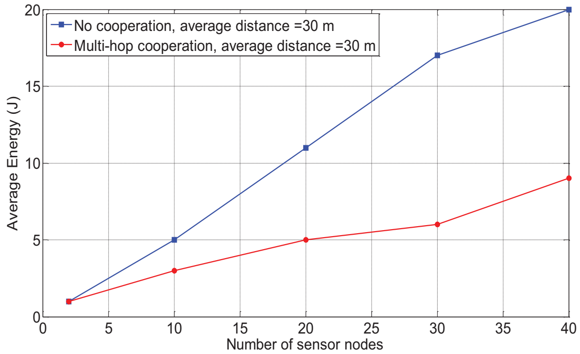

Fig. 7. Average energy consumption vs. the number of sensor nodes for different values of averagedistance between nodes

Figure 7 illustrates the energy consumption results without normalization, It shows that the energy is reduced when the distance to the BS is reduced, as expected. The results of the energy consumption in the cooperative and non-cooperative scenario are shown in figure 7

B. Comparison

There are two types of ad-hoc routing protocols: table driven and source initiated. Table driven protocols are Destination-Sequenced Distance-Vector Routing (DSDV), Cluster head Gateway Switch Routing (CGSR), Wireless Routing Protocol (WRP) etc. Source initiated protocols are Ad hoc on Demand distance Vector (AODV), Dynamic Source Routing (DSR), Temporally Ordered Routing Algorithm (TORA), Signal Stability Routing (SSR), Lightweight Mobile Routing (LMR), Associativity-Based routing (ABR) etc. Here a comparison between some of these algorithm and proposed algorithm is discussed,where same scenario is considered. AODV selects its shortest path considering hop count parameter. From the graph in figure 8 it can be stated that based on the variety of parameters proposed algorithm outperforms over AODV considering (BER).

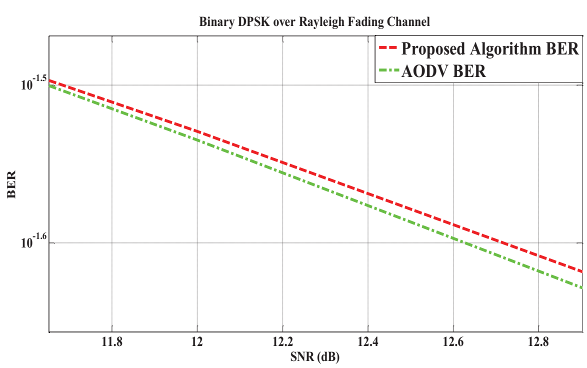

Fig. 8. Comparison Graph considering BER with AODV

DSDV selects its shortest path considering hop count parameter. As it uses routing table, extra battery life is used. But Doppler shift, batterylife, queue length/delay are not considered in DSDV. It can be stated that, DSDV has far more BER than proposed algorithm, shown in figure 9. So, proposed algorithm is more reliable in consideration with BER.

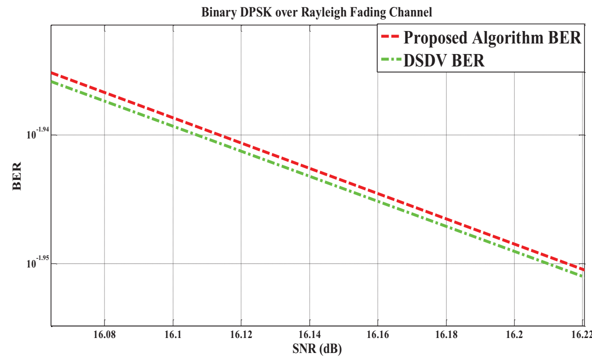

Fig. 9. Comparison Graph considering BER with DSDV

DSR selects its shortest path considering packet delivery, average end-to-end delay and average energy per packet. But, Doppler Shift is not considered in DSR. From figure 10 it can be stated that, proposed algorithm offers lower BER in contrast with DSR.

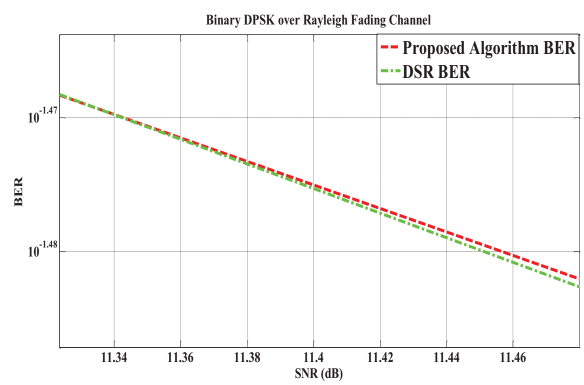

Fig. 10. Comparison Graph considering BER with DSR

SSR selects its shortest path considering Doppler shift and signal strength. But, Queueing length/delay is not considered in SSR. From the graph in figure 11 it can be stated that, proposed algorithm surpasses over SSR considering (BER).

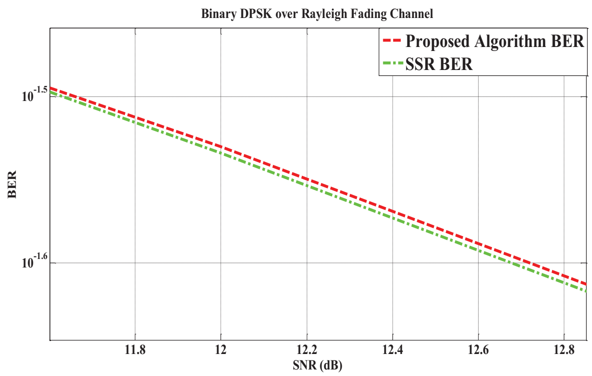

Fig. 11. Comparison Graph considering BER with SSR

TORA selects its shortest path considering end-to-end delay and throughput. But, Doppler shift is not considered in TORA. From the graph in figure 12 it can be stated that, TORA has more BER than proposed algorithm. So, proposed algorithm is more satisfactory having considered BER.

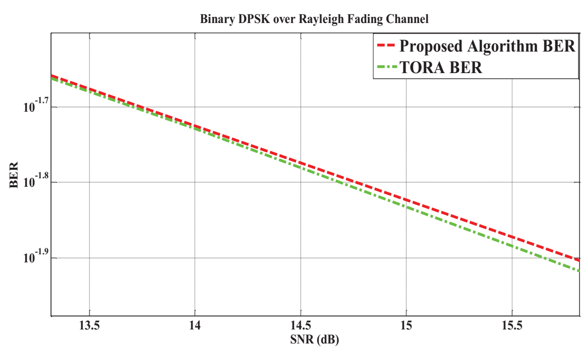

Fig. 12. Comparison Graph considering BER with TORA

VI. Conclusion

This work focuses on developing a neuro-fuzzy based adaptive routing algorithm for wireless ad-hoc network. This work produces an energy efficient and reliable routing algorithm.This algorithm defines the shortest path using weight calculation where BER, Doppler Shift, End-to-End delay, Battery Life and Reliablity is considered. The performance of our algorithm is compared with existing algorithms in consideration with BER. This work can be extended by implementing the protocol in real-life scenario.

References

[1] Prof.Dr.R. Wattenhofer, "Ad hoc and Sensor Networks," University Salerno, Italy, July 2009.

[2] C.-K. Toh, "Ad Hoc Mobile Wireless Networks: Protocols and Systems,", Prentice Hall, December 2001.

[3] J. Kuruvila, A. Nayak, I. Stojmenovic, "Hop count optimal position-based packet routing algorithms for ad hoc wireless networks with a realistic physical Layer," Published in Journal IEEE Journal on Selected Areas in Communications archive, Vol. 23, Issue 6, pp. 1267-1275, September 2006.

[4] P. Srinivasan, P. Kamalakkannan, "REAQ-AODV: Route stability and energy aware QoS routing in mobile Ad Hoc networks," Fourth International Conference on Advanced Computing (ICoAC), December 2012.

[5] P. Sasikumar, M. Abraham Roy, "Analysis of Power Saving Routing Protocol for Wireless," International Journal of Computer Applications, December 2010.

[6] L. Marie Feeney, "An energy consumption model for performance analysis of routing protocols for mobile ad hoc networks," Published in Journal Mobile Networks and Applications, Vol. 6, Issue 3, pp. 239 - 249, June 2001.

[7] A. S. Kopekar, A. S. Dhakate, A. Kale, "Performance evaluation of routing algorithms for adhoc wireless sensor network and enhancing the parameters for good throughput," , International journal of applied information systems(IJAIS), Vol. 3, No. 6, July 2012.

[8] I. Chlamtac, M. Conti, J. J.-N.Liu, "Mobile adhocnetworking:imperatives and challenges,", Ad Hoc Networks, Vol. 1,Issue 1, pp. 1364, July 2003.

[9] Y. Wu, C. Fellow, Q. Zhang, K. Jain, W. Zhu, S. Yuan, "Network planning in wireless adhoc networks: A crosslayer approach," IEEE journal on selected areas in communications, vol. 23, No. 1, January 2005.

[10] N. Bansal, Z. Liu, "Capacity,Delay and Mobility in wireless adhoc networks," INFOCOM 2003. Twenty-Second Annual Joint Conference of the IEEE Computer and Communications. IEEE Societies, Vol. 2, April 2003.

[11] K. Albarazi, U. Mohammad, N. Al-holou, "Doppler shift impact on vehicular adhoc networks," Canadian journal on multimedia and wireless networks, Vol. 2, No. 3, August 2011.

[12] S. K. Kanhere, M. Goudar, V. M. Wadhai, "End-To-End Delay Optimization in Wireless Sensor Network (WSN)," International Journal of Smart Sensors and Ad Hoc Networks (IJSSAN) ISSN No. 2248-9738 Vol. 1, Issue 3, 2012.

[13] V. Dyo, C. Mascolo, "Efficient node discovery in Mobile Wireless Sensor Network," DCOSS '08 Proceedings of the 4th IEEE International Conference on Distributed computing in Sensor Systems, 2008.

[14] Y. Cao, Z. Zhong , Y. Gu and T. He, "Safeguarding Schedule Updates in Wireless Sensor Networks," Mini-Conference at IEEE INFOCOM, 2011.

[15] O. Dousse, P. Mannersalo, P. Thiran, "Latency of Wireless Sensor Networks with Uncoordinated Power Saving Mechanisms," MobiHoc '04 Proceedings of the 5th ACM International Symposium on Mobile ad hoc networking and computing, pp. 109-120, May 2004.

[16] S. Lindsey, C. Raghavendra and K. M. Sivalingam, "Data Gathering Algorithms in Sensor Networks Using Energy Metrics," IEEE Trans. On Parallel Distrib. Syst., Vol. 13, no. 9, September 2002.