A Noble Dead-end free Three-Dimensional Routing and Scheduling Techniques for Multi-Hop Wireless Networks

[1]Afruza Begum, [2]Md Anwar Hussain
Department of Electronics and Communication Engineering
North Eastern Regional Institute of Science and Technology
Nirijuli, Arunachal Pradesh, India
[1]afruza.moon@gmail.com, [2]bubuli_99@yahoo.com,

[3]S Md S Askari
Department of Computer Science and Engineering
Rajiv Gandhi University
Arunachal Pradesh, India
[3]askari.sikdar@gmail.com

***Abstract*—Multi-hop wireless networks are essential for communication infrastructure. Efficient routing techniques are very important for enhancing multi-hop wireless communication system. Most of the recent routing protocols are designed for two dimensional space, in real life scenario some nodes may be in 3D space. Dead-end is a critical issue in wireless networks when routing packets in a large geographical area. In this paper we have proposed dead end free 3D distributed routing protocol for multi-hop wireless networks based on minimum angle. Here we have presented the dead end router management technique for the 3D minimum angle routing protocol (3DMA). Through extensive simulation we have shown how dead end management is done and calculated the end to end throughput, delay and energy consumption for each user.**

Keywords*—*Multi-Hop, Dead End, Routing, Throughput, Three-dimension, Protocol

I. Introduction

Multi-hop wireless network is very essential in modern communication infrastructure. It has been experiencing modernization which guarantees momentous impact on humanity. In practice multi-hop wireless networks modeled by Wireless Sensor Networks[16], Mobile Ad-hoc Networks, Wireless Mesh Networks and Vehicular Ad-hoc Networks[5] without any infrastructure [1]. Communication happens through radio range, two nodes U and V can communicate with each other if they are within transmission range of each other [4]. The longer distance communication, outside of transmission range, is done through one or more intermediate nodes used as a relay/forwarder towards the destination, this concept is called multi-hop wireless networks. Wireless networks consists of large number of nodes spread over geographic area, it is very important to design routing and scheduling techniques which is efficient dead end free and provide best path to reach destination with, maximum throughput and less delay.

Most of the recently proposed routing protocols are designed for 2D spaces. These protocols are not applicable in real life 3D scenario like air or space, underwater etc [2]. 3D embedding gives more accurate network behavior in real world applications [8] like forest fire monitoring [15][3], under water or ocean monitoring [17][11][7], atmosphere oe air [18] etc. From our study so far, we have found very less number of efficient three dimensional routing protocols have been proposed, may be because of designing of a 3D routing protocols are surprisingly more difficult than designing 2D routing protocols. Thats why we are motivated to develop efficient routing and scheduling techniques for challenging three dimensional environments.

In this paper we have presented a dead end free 3D routing protocol for multi-hop wireless networks based on minimum angle. Afruza et al.[4] proposed a 3D routing and scheduling techniques for multi-hop wireless networks based on minimum angle (3DMA), there is a problem of dead end in routing path. Here we have mainly focused on dead end router management techniques for 3DMA routing protocol. 3DMA is a distributed routing protocol, in which the sender node selects next hop forwarder for sending data packets to the destination, from the set of neighbors, within its transmission range which makes minimum angle with the reference line drawn from sender to destination and it repeats the same procedure until it gets the destination, if there is a path and if there is no path to forward packets to the destination i.e. a dead end problem is encountered at the first minimum angled neighbor then it will remove this minimum angled node from the selected path list and will select the second minimum angled neighbor as intermediate node in the path list, and will proceed with the minimum angled selection procedure of 3DMA to forward the packet to the destination, if there is path. And if it encounters the dead end again then it will remove the second minimum angled node from the path list selecting the third minimum angled neighbor if any and will try to proceed as before, and if again it faces the dead end situation then it will remove this third angled node too from the path list, looking for a minimum distance node from the rest of the neighbors if any. If there is no neighbor left or again dead end is encountered, then it will backtrack to the previously selected intermediate node removing this minimum distance node from the path list. From this intermediate node same procedure will be followed up until it gets the final path from the sender to destination.

This paper is organized as follows. Section II is the related works, section III is the methodology, section IV is the analysis of results and finally section V is the conclusion and future works.

II. Related Works

Now a days research in three dimensional routing in multi-hop wireless networks is gaining popularity because many applications such as underwater monitoring, forest fire detection, air space or atmosphere monitoring, etc. need three dimensional routing for gathering information. In [14] Wang et.al proposed an efficient sub minimal ellipsoid geographical greedy face routing protocol (EGE3D). In this protocol when a neighbor node of the sender is set to one point in the ellipse, a vertical ellipse region is uniquely shaped. Ellipse zone is constructed from one neighbor node by this sender node and determines that this neighbor on the ellipse will keep the second least angle (sub minimal) to the line from source to destination, the packets are forwarded greedily until a local minimal is obtained inside the sub minimal ellipse. Here to avoid void node problem (VNP) they have used face algorithm. How to construct a 3D wireless sensor networks, how to achieve low connectivity and full coverages by using less number of sensors using wireless sensor networks, this problem is studied by Zhang et al.[19]. The authors designed a set of patterns that achieve the full coverage and K connectivities where $k <= 4$. They have proved the optimality of 1-, 2-, 3- and 4-connectivity and full-coverage, among regular lattice deployment patterns and proved their optimality under any value of the ratio of communication range (rc) over sensing range (rs). They have compared with 14-connectivity and observed when $rc/rs = 1$ the number needed to achieve 14-connectivity is around 2.5 times that the number needed to achieve 3- or 4- connectivity and 3.5 times that the number needed to to achieve 1- or 2- connectivity. The number difference increases as the ratio rc/rs decreases. They also have investigated the evolutions among all the proposed low-connectivity patterns In [8] the authors presented the design philosophy and basic principle like neighbor selection rules, routing hole bypass approaches and classifications of 3D geographic routing (3DGR) protocols and categorized current research work based on different criteria. They compared 3DGR from a variety of perspective and applications like, guaranteed delivery, path quality, reactive, distributed, complexity and communication overhead. They also have discussed various issues of 3DGR routing protocols like, limitations of networks model, lack of multidimensional geographic routing, lack of security in geographic routing protocols. Rubeaai et al. [2] have proposed a three-dimensional real-time routing protocol (3DRTGP) for wireless sensor networks. This protocol achieves real-time routing operations using adaptive packet forwarding region (PFR) and selecting fast forwarding nodes in the PFR. The PFR technique limits the number of nodes forwarding towards destination. They have given a heuristic solutions for void node problem in 3D wireless sensor networks. The 3DRTGP gives tuning techniques to make the protocol meet the delay and miss ratio requirements of applications. Shah and Kim[13] studied and discussed the various issues related to 3D wireless ad-hoc and sensor networks, mainly they have studied 3D underwater sensor networks (UWWSN) 3D airborne ad-hoc networks (AANET's). Design requirements and challenges in 3D, AANET's and UWWSN are discussed throughly. They also have highlighted the various research issues in 3D wireless ad-hoc and sensor networks. Fariborz Entezami and Christos Politis[6] have proposed a novel, real-time, position based and energy efficient routing protocol 3DPBARP, for WSNs based on spanning tree method. They have used greedy forwarding approach when looking for a path to the destination. The protocol uses unique restricted parent forwarding regions (PFR), that reduces the range of radio frequency to cover minimum number of nodes, only the parent nodes. It reduces the number of forwarding nodes as a result it improve in traffic and packet collision. They have used rainbow mechanism to avoid dead end routes. In [12] the authors proposed joint routing, scheduling and power control in multi-hop wireless network using linear relation between link capacity and interference noise ratio.

In [10] and [9] Hussain et al. have presented a simple two dimensional routing and scheduling technique for multi-hop wireless networks based on minimum angle and minimum angle intermediate node for 2D spaces. In [4] Afruza et al. have implemented 3DMA distributed routing protocol for 3D spaces, here when nodes are distributed randomly in the network, the 3DMA protocol [4] suffers from dead end router problem. From the literature survey so far, it is observed that the dead end router problem is a major issue in wireless networks and it is hardly addressed by the existing works. So we are motivated to find a solution to this dead end router problem. In this work we have implemented the 3DMA[4] with dead end router management technique for 3D spaces, in which it tries to find a path in all possible ways.

III. 3DMA PROTOCOL DESIGN

Consider a set of n wireless nodes is distributed in a 3D plane $\{X,Y,Z\}$. Each node knows the location of its own, location of neighbors, location of destination and all other nodes in the networks through GPS or some other centralize location management techniques. All the nodes in the networks have the transmission range R. Two wireless nodes $U(u_x, u_y, u_z)$ and $V(v_x, v_y, v_z)$ can communicate with each other if Euclidean distance between U and V satisfies the following equation-1

$$\|UV\| <= R \tag{1}$$

Where R is the radio transmission range, and $\|UV\|$ is the Euclidean distance between U and V and it is defined by the following equation-2

$$\|UV\| = \sqrt{(u_x - v_x)^2 + (u_y - v_y)^2 + (u_z - v_z)^2} \tag{2}$$

When the nodes of wireless networks are spread uniformly over large geographic area, dead end is a serious issue. Dead end means, when a sender is sending packets to destination, in the middle of the path there the situation may arise that no further nodes are there to forward packets to the destination. Therefore a good routing techniques is very much important so that the packets can be sent managing this dead end routing situation from source to destination through intermediate nodes. Afruza et al.[4] proposed a noble 3D routing and scheduling techniques 3DMA for multi-hop wireless networks. There it is considered that in the network the nodes are uniformly distributed in a 3D plane. But in real life scenarios nodes may not be distributed uniformly so dead end scenario may arise. Here we have added the dead end router management techniques to the 3DMA protocol[4].

In 3DMA routing protocol first a reference line is drawn from sender to destination. For Sender $S(s_x, s_y, s_z)$ and Destination $D(d_x, d_y, d_z)$, equation of line drawing from S to D is given by the following equation-3

$$\overrightarrow{PQ} \leftarrow (s_x - d_x, s_y - d_y, s_z - d_z) \quad (3)$$

Where $\overrightarrow{PQ}$ is the straight line in a 3D space, s_x, s_y, s_z and d_x, d_y, d_z are the positional coordinates of sender S and destination D respectively.
Then the sender selects the intermediate/relay node from the set of neighbors of the sender which makes minimum angle with reference line drawn from sender to destination. Repeats this process until it gets the destination if there is no dead end in the path. Angle θ made by a node N from list of neighbor nodes, with the reference line drawn from sender S to destination D is calculated by the equation-4 given bellow

$$\theta = \cos^{-1}\left[\frac{\overrightarrow{SN} \cdot \overrightarrow{SD}}{||\overrightarrow{SN}||\,||\overrightarrow{SD}||}\right] \quad (4)$$

Where $(\overrightarrow{SN} \cdot \overrightarrow{SD})$ is the dot product of $\overrightarrow{SN}$ and $\overrightarrow{SD}$, $||\overrightarrow{SN}||$ and $||\overrightarrow{SD}||$ is the euclidean vector norms.

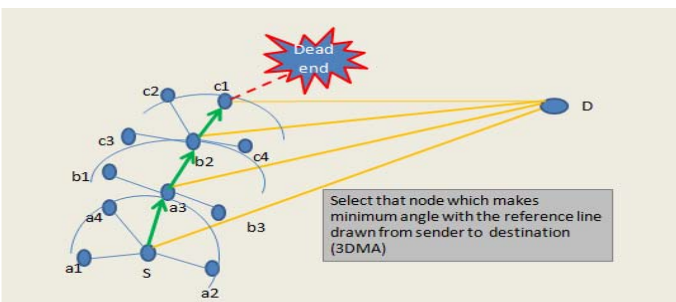

Fig. 1. Dead end Problem

Repeat the same procedure till its reaches to the destination. If any dead end is encountered in the path, as shown in figure-1 in 3DMA routing protocol [4]. Here sender node is denoted by S and destination is denoted by D. A reference line is drawn from S to D. a_1,a_2, a_3 and a_4 is the neighbor of S. Assume that a_3 makes minimum angle with reference line $\overrightarrow{SD}$, so a_3 is selected as a intermediate node towards destination D and a reference line is drawn from this selected IM a_3 to D. b_1, b_2 and b_3 are the neighbors of a_3, it is assumed that from the neighbor list of a_3, b_2 makes minimum angle with the reference line $\overrightarrow{a_3D}$, b_2 added as a IM in the selected path list and a reference line is drawn from b_2 to D. In the same way c_1 is selected as a IM and added to the path list from the neighbor list of b_2.

A. Dead End Management Technique of 3DMA

Now suppose the situation arises as shown in figure-1 that there is no node within the transmission range of c_1 to forward packets to the destination D, i.e encounters a dead end, then to avoid dead end and to find some others alternate route following steps are followed:

1. It will remove the last selected node from the path list and will select the second minimum angle node if any in the neighbor set of sender (b_2) as an intermediate/relay node to forward packets to the next step towards destination. Suppose c_2 forms second minimum angle from the neighbor list of immediate sender b_2, so c_2 will be selected as IM and will be added to the path list for forwarding towards destination D as shown in figure 2 and will follow the 3DMA IM selection procedure to forward packets towards destination if there is path.

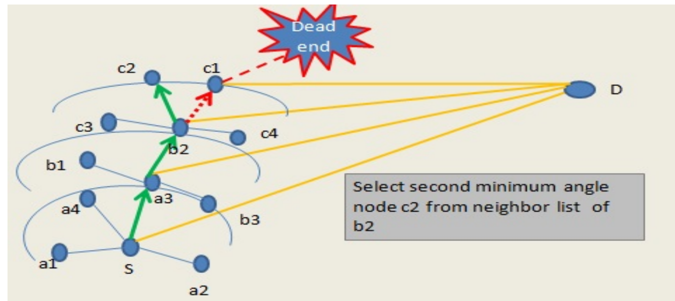

Fig. 2. Selection of second minimum angle node from neighbor list

If it encounters a dead end again from second minimum angle node (c_2) then it will go to step-2

2. It will remove the last selected node from the path list, and will select the third minimum angle node and will add it to the path list, from neighbor list of sender (b_2) if any and go ahead towards destination following 3DMA IM selection procedure if there is path, if there is no path i.e. dead end, then removing this last node from the path list, it will select the minimum distance node, if any and will add to the path list as shown in figure-4, and will proceed towards destination with 3DMA IM selection procedure. Assume c_3 is the 3rd minimum angle and c_4 is the minimum distance node of b_2 as shown in figure-3 and 4.

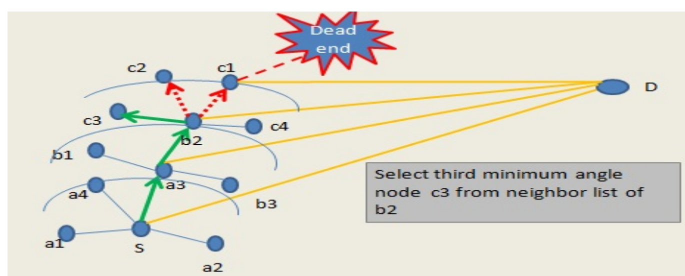

Fig. 3. Selection of third minimum angle node from neighbor list

If there is no path from c_3 or from c_4 to forward towards destination then it will go to step-3.

3. Removing this c_3 or c_4 from the path list it will backtrack to the previous selected IM in the selected path list, and will apply the step-1 (selection of 2nd minimum angle) and 2 (selection 3dr minimum angle and minimum distance node) as shown in figure-5, to go ahead towards destination. If no path is found this backtracking process will repeat as shown in figure-6 until it reaches the original source node (S) and will select the minimum distance node from the original source node S as a intermediate node and repeat the 3DMA route selection

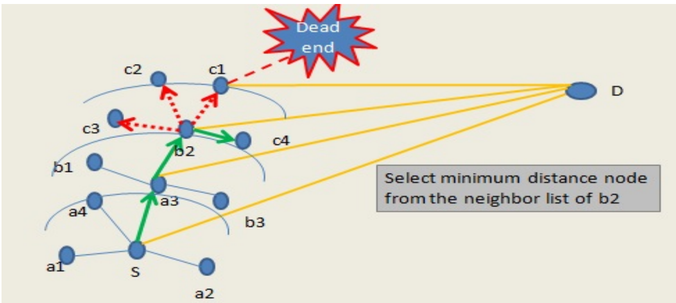

Fig. 4. Selection of minimum distance node among all neighbors

procedure and the dead end router management technique till it reaches to the destination.

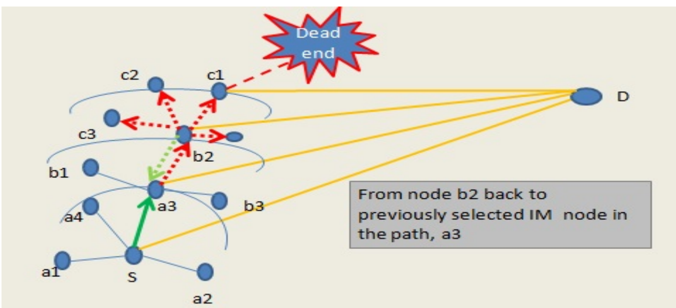

Fig. 5. Back to previous IM in the selected routing path.

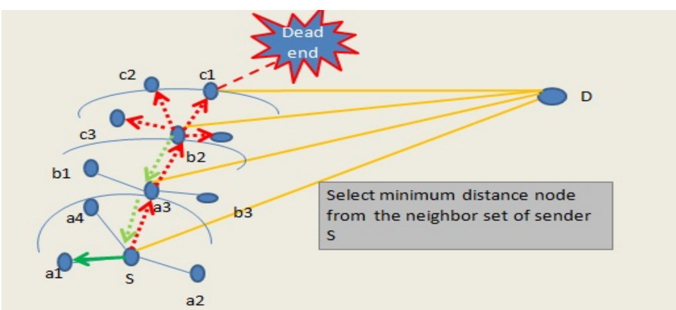

Fig. 6. Back to the original sender noder node.

The dead end management technique described above in point 1 (selection of 2nd minimum angle) and 2 (selection 3dr minimum angle and minimum distance node) will not execute if there is single neighbor of the sender (b_2), in this case only the step-3 will be executed to backtrack to previous IM in the selected path list. In figure-7 we have shown the simulation output of 3DMA routing protocol using dead end management technique for one user. From sender it goes through node a_1 and a_2 as an IM to forward packets towards destination (base station), but at a_2 it encounters dead end so it will backtrack (shown by black cursor), and it finds a new path to the destination.

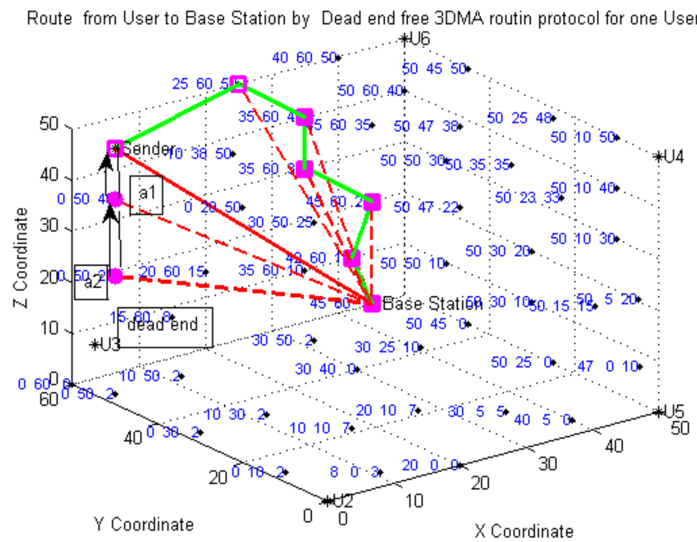

Fig. 7. Route for one user in a 3D plane by 3DMA routing protocol using the dean end management technique

IV. Performance Evaluation

Performance of the proposed routing techniques is evaluated by calculating End to End Throughput and Energy Consumption of each route from source to destination through simulation in Matlab Platform. For simulation purpose we have considered networks of 70 to 200 node distributed randomly in a 3D plane $\{X, Y, Z\}$. Each node has a transmission rang of 18 m. All the nodes scatter in the network can be source or destination, we have considered some of them as sender (User) node and one of them as a destination (Base Station). We have considered each node in the network knows the location of itself and others nodes in the network through GPS or some other location management techniques. Simulation perimeter which are considered common for all nodes are tabulated in table in table-I.

TABLE I: Network simulation parameters

Network parameter	Value
Data packet size	1 MB
Network Area	$50m \times 60m \times 50m$
Number of nodes	80 to 150
Range of node	18 m
E_{elec}	50nJ/bit
E_{amp}	$100pJ/bit/m^2$
Number of Sender	6

We have assumed that each node have burst profiles with modulation and coding rates to obtain different data rates with different transmission distances.

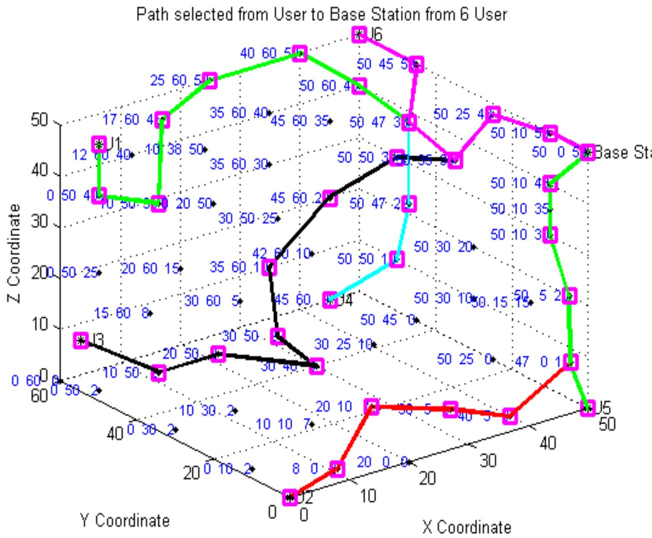

Fig. 8. Route constructed by dead end free 3DMA routing protocol for First Network

TABLE II: Performance Analysis of first Network shown in figure-7

Sender	ETH (Mbps)	No. of IM	Time(Sec)	Energy (Joule)
Sender1	0.7500	10	1.3333	1.53×10^{28}
Sender2	0.9167	8	1.0909	1.06×10^{28}
Sender3	0.7500	10	1.3333	1.63×10^{28}
Sender4	1.1786	6	0.8485	1.11×10^{28}
Sender5	1.6500	4	0.6061	0.53×10^{28}
Sender6	1.3750	5	0.7273	0.90×10^{28}

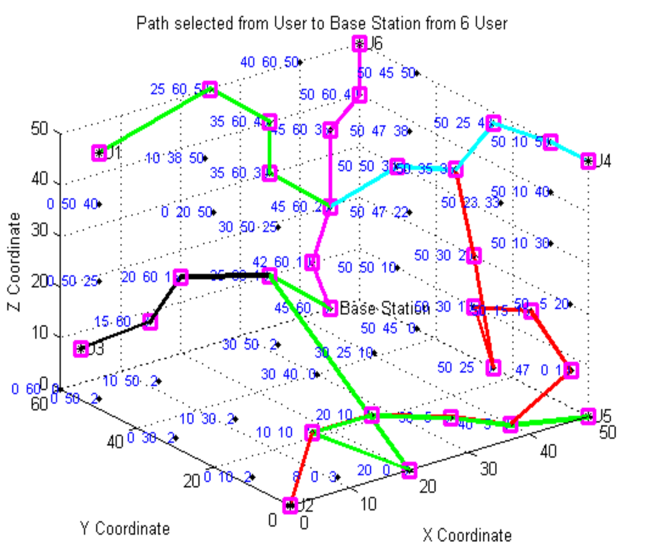

Fig. 9. Route constructed by dead end free 3DMA routing protocol for First Network

TABLE III: Performance Analysis of first Network shown in figure-8

Sender	ETH (Mbps)	No. of IM	Time(Sec)	Energy (Joule)
Sender1	1.0313	5	0.9697	1.54×10^{28}
Sender2	0.5156	13	1.9394	2.22×10^{28}
Sender3	2.0625	3	0.4848	0.56×10^{28}
Sender4	1.1786	6	0.8485	1.03×10^{28}
Sender5	0.5789	6	1.7273	3.89×10^{28}
Sender6	1.6500	4	0.6061	0.47×10^{28}

Figure 7 and figure 8 shows the selected routing path from sender (user) to destination (Base Station) considering each network has 6 sender (user) and one destination (base station). In the network-1 as shown in figure-8, we have considered the destination (base station) at the upper right edge and 6 sender is situated in all the other edge and the center of the network, in network-2, we have considered Base station (destination) is in the center and users are situated in all the edges of the network. The performances of dead end free 3DMA protocol are tabulated in Table-II and table-III, i.e. end to end throughput, number of intermediate nodes (IM), times needed to travel and energy consumption in routing path for each sender to reach the destination. The table-II and table-III show that throughput increases with the decreases of travel time and number of intermediate hops in the routing path. When throughput increases it decreases the energy consumption for sending data packets. From figure-7 and 8, the simulation output results we can see that, implementing the dead end router management technique to the 3DMA [4], it finds a path from sender to destination in almost all possible ways in a network where the nodes of the network are distributed randomly. It may took long path, more intermediate nodes but it will find path somehow with the dead end management techniques.

V. Conclusion and Future Work

In this paper we have presented a dead end router management techniques for our earlier implemented three dimensional routing protocol 3DMA[4]. Through simulation, the performance evaluation is done by calculating end to end throughput and energy consumption. This protocol resolves the dead end router problem of multi-hop wireless networks for 3D space. This dead end free 3DMA may chose long route when it encounters a dead end but finds a path to reach the destination by trying all possible ways in case of nonuniform 3D networks. In the current version of this protocol, one user can send at a time to the destination. we are working on developing efficient scheduling techniques so that more than one user can send at a time without interference, considering nodes mobility of wireless network and will compare the performance of our routing and scheduling techniques with others existing 3D routing and scheduling techniques.

Acknowledgement

This research work is fully supported by Visvesvaraya full time PhD Scheme, MeitY, Government of India. Authors are thankful to the MeitY,GoI.

References

[1] Alaa E Abdallah. Smart partial flooding routing algorithms for 3d ad hoc networks. *Procedia Computer Science*, 94:264–271, 2016.

[2] Sarab F Al Rubeaai, Mehmmood A Abd, Brajendra K Singh, and Kemal E Tepe. 3d real-time routing protocol with tunable parameters for wireless sensor networks. *IEEE Sensors Journal*, 16(3):843–853, 2016.

[3] Ahmad Aa Alkhatib, Mohammad Alia, and Adnan Hnaif. Smart system for forest fire using sensor network. *INTERNATIONAL JOURNAL OF SECURITY AND ITS APPLICATIONS*, 11(7):1–16, 2017.

[4] Afruza Begum, Md Anwar Hussain, Joyatri Borah, and S Md S Askari. A simple three-dimesional joint routing and scheduling protocol for multi-hop wireless networks. In *4th IEEE International Conference on Recent Advances in Information Technology, 2018*. IIT(ISM), Dhanbad, India, in press 2018.

[5] Tasneem Darwish and Kamalrulnizam Abu Bakar. Traffic aware routing in vehicular ad hoc networks: characteristics and challenges. *Telecommunication systems*, 61(3):489–513, 2016.

[6] Fariborz Entezami and Christos Politis. Three-dimensional position-based adaptive real-time routing protocol for wireless sensor networks. *EURASIP Journal on Wireless Communications and Networking*, 2015(1):197, 2015.

[7] Guangjie Han, Jinfang Jiang, Na Bao, Liangtian Wan, and Mohsen Guizani. Routing protocols for underwater wireless sensor networks. *IEEE Communications Magazine*, 53(11):72–78, 2015.

[8] Haojun Huang, Hao Yin, Yan Luo, Xu Zhang, Geyong Min, and Qilin Fan. Three-dimensional geographic routing in wireless mobile ad hoc and sensor networks. *IEEE Network*, 30(2):82–90, 2016.

[9] Md Anwar Hussain and Arifa Ahmed. A simple optimized joint routing and scheduling algorithm for multi-hop wireless network. In *Electronics, Communications and Networks IV: Proceedings of the 4th International Conference on Electronics, Communications and Networks (CECNET IV), Beijing, China, 12–15 December 2014*, page 117. CRC Press, 2015.

[10] Md Anwar Hussain, Md Faiz Iqbal Faiz, and Ishita Chakraborty. Simple routing algorithm for multi-hop wireless network. *Journal of Emerging Trends in Computing and Information Sciences*, 4:58–65, 2009.

[11] Jinfang Jiang, Guangjie Han, Hui Guo, Lei Shu, and Joel JPC Rodrigues. Geographic multipath routing based on geospatial division in duty-cycled underwater wireless sensor networks. *Journal of Network and Computer Applications*, 59:4–13, 2016.

[12] Javad Kazemitabar, Vahid Tabatabaee, and Hamid Jafarkhani. Joint routing, scheduling and power control for large interference wireless networks. *Journal of Communications and Networks*, 19(4):416–425, 2017.

[13] Babar Shah and Ki-Il Kim. A survey on three-dimensional wireless ad hoc and sensor networks. *International Journal of Distributed Sensor Networks*, 10(7):616014, 2014.

[14] Zhixiao Wang, Deyun Zhang, Omar Alfandi, and Dieter Hogrefe. Efficient geographical 3d routing for wireless sensor networks in smart spaces. In *Internet Communications (BCFIC Riga), 2011 Baltic Congress on Future*, pages 168–172. IEEE, 2011.

[15] Zhiyong Wang, Sisi Zlatanova, Aitor Moreno, Peter Van Oosterom, and Carlos Toro. A data model for route planning in the case of forest fires. *Computers & Geosciences*, 68:1–10, 2014.

[16] Su Xia, Xiaotian Yin, Hongyi Wu, Miao Jin, and Xianfeng David Gu. Deterministic greedy routing with guaranteed delivery in 3d wireless sensor networks. *Axioms*, 3(2):177–201, 2014.

[17] Ming Xu, Guangzhong Liu, and Huafeng Wu. An energy-efficient routing algorithm for underwater wireless sensor networks inspired by ultrasonic frogs. *International Journal of Distributed Sensor Networks*, 10(2):351520, 2014.

[18] Wei Ying Yi, Kin Ming Lo, Terrence Mak, Kwong Sak Leung, Yee Leung, and Mei Ling Meng. A survey of wireless sensor network based air pollution monitoring systems. *Sensors*, 15(12):31392–31427, 2015.

[19] Chuanlin Zhang, Xiaole Bai, Jin Teng, Dong Xuan, and Weijia Jia. Constructing low-connectivity and full-coverage three dimensional sensor networks. *IEEE Journal on Selected Areas in Communications*, 28(7), 2010.