A Simple Three-Dimensional Joint Routing and Scheduling Protocol for Multi-Hop Wireless Networks

[1]Afruza Begum, [2]Md Anwar Hussain, [4]Joyatri Bora
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, [4]bjoyatri@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 becoming more and more advanced in its technology. In this paper we have presented a simple three-dimensional minimum angle (3DMA) routing and scheduling protocol for multi-hop wireless networks. The 3DMA routing protocol is a distributed routing protocol, in which a sender selects the next hop as forwarder/relay node form the set of its neighbors, for sending data packets towards destination, which node makes minimum angle with the reference line drawn from source to destination. We have implemented the 3DMA algorithm in such a way, that it is always loop free and needs minimum number of hops to reach the destination. Through simulation, performance evaluation and result analysis of 3DMA is done by calculating the end-end throughput and Energy Consumption for each sender for sending data packets from source to destination. Analysis of output results are done by changing location of user, destination and nodes of the network.**

***Keywords*—Multi-Hop, routing, scheduling, throughput, three-dimension, protocol**

I. Introduction

In last few decades a huge number of routing protocols have been proposed, most of them are for two dimensional spaces. These protocols are not applicable in complicated and challenging three dimensional spaces like underwater, air etc. In practice multi-hop wireless networks (mobile ad-hoc networks, wireless sensor networks, wireless mesh networks, vehicular ad-hoc networks etc.) are often deployed in three dimensional spaces for various important applications such as sky space or atmosphere that is airborne network [16][14]; ocean monitoring that is underwater sensor networks [18][6][7][22][17][10]; forest fire monitoring [3][2] and others[1]. Generally 3D embedding gives more accurate network behavior in real world applications [11]. Three dimensional routing protocols are important to gather and collect those phenomena which cannot be collected by 2D routing protocols. The 3D routing techniques provide number of applications for scientific, environmental, commercial and military purpose [4][5] including disaster prevention, pollution monitoring[15], seaward exploration and oil/gas monitoring etc[20][19]. Airborne networks provide air-to-air, surface-to-air and sometimes surface-to-surface communications. In military at the time of war airborne network can enable military planes to communicate with platoons or solders on the ground without any fixed infrastructure[20]. From our study so far, we have found very less number of efficient three dimensional routing protocols have been proposed, because designing of 3D routing protocols are surprisingly more difficult than designing 2D routing protocols. Its a hot topic for the researcher to develop efficient, reliable routing techniques for three dimensional approach. Hence we are motivated to develop efficient routing and scheduling techniques for challenging three dimensional environments.

To obtain the location information in three dimensional coordinates(latitude, longitude, altitude) [20] GPS (Global Positioning System)[8] and other similar techniques are used. Geographical routing protocols do not need route discovery and route maintenance like topological routing algorithms therefore dynamic changes in network can be adjusted easily[1].

We have considered multi-hop wireless network, where each node knows its own location, locations of neighbors and other nodes in the network using centralized location management technique like GPS or locations are pre decided before deployment. Nodes in the network receive and forward packets through one or more intermediate nodes using wireless link for the communication between two end points[13]. In this paper, we have presented a simple three dimensional minimum angle based routing protocol (3DMA). In 3DMA a reference line is drown from source to destination, all the nodes within the transmission range of the sender node are selected as a set of neighbors of the sender, and draws lines connecting the neighbors and the source, forming angles for every neighbor with the reference line. The neighbor that creates minimum angle is selected as a next hop node for forwarding packets to the destination.

This paper is organized as follows. Section II is the related works, section III is the methodology and algorithm, section IV is the performance evaluation and analysis of result and finally section V is the conclusion.

II. Related Works

Research in three dimensional routing in multi-hop wireless networks is gaining popularity because many applications such as air space or atmosphere monitoring, underwater monitoring, forest fire detection, etc. needs three dimensional routing for gathering informations. Wang et.al [23] proposed an efficient sub minimal ellipsoid geographical greedy face routing protocol (EGE3D). In EGE3D a vertical ellipse region is uniquely shaped

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when neighbor nodes of the sender is set to one point in the ellipse. 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, where inside the sub minimal ellipse the packets forwarded greedily until a local minimal is obtained. They have used face algorithm to avoid void node problem (VNP). Rubeaai et al. [1] have proposed a three-dimensional real-time routing protocol (3DRTGP) for wireless sensor networks.This protocols achieve real-time routing operations using adaptive packet forwarding region (PFR) and selecting fast forwarding nodes in the PFR. PFR technique limits the number of nodes forwarding towards destination. They have given a heuristic solution 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. In [11] 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. Shah and Kim[20] studied and discussed the various issues related to 3D wireless ad-hoc and sensor networks, mainly about 3D airborne ad-hoc networks (AANET's) and 3D underwater sensor networks (UWWSN). 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[9] have proposed a routing protocol 3DPBARP which is a novel, real-time, position based and energy efficient protocol 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), to cover only the parent node, which reduces the radio range so that minimum number of nodes are covered. It reduces the number of forwarding nodes as a result improve in traffic and packet collision.They have used rainbow mechanism to avoid dead end routes. Zhang et al.[24] studied the problem of how to construct a 3D wireless sensor networks that achieves low connectivity and full coverages by using less number of sensors. They have designed a set of patterns to achieve the full coverage and K connectivity where $k <= 4$. They have proved the optimality of 1-, 2-, 3- and 4-connectivity and full-coverage, and proved their optimality under any value of the ratio of communication range rc over sensing range rs, among regular lattice deployment patterns. 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 to achieve 3- or 4- connectivity and 3.5 times that to achieve 1- or 2- connectivity. The number difference increases as rc/rs decreases. They also have investigated the evolutions among all the proposed low-connectivity patterns. In [13] and [12] Hussain et al have presented a simple routing and scheduling techniques for multi-hop wireless networks based on minimum angle and minimum angle intermediate node. Earlier we have implemented the protocol for 2D spaces, in this work we have implemented the 3DMA for 3D spaces considering some other issues of 3D scenario.

III. 3DMA PROTOCOL DESIGN

In the design of 3DMA routing protocol, it is assumed that each node knows its own location, location of neighbors and the destination location, using GPS or some other centralized location management techniques. We have considered that nodes are homogeneous and distributed randomly in a three dimensional plane. Suppose a 3D multi-hop wireless network consists of a set V of n nodes distributed in a 3D plane $\{X, Y, Z\}$. Each node has transmission range TR. Two nodes u and v can receive and send signal directly if the following equation-1 is satisfied.

$$\|uv\| \leq TR, \tag{1}$$

where $\|uv\|$ is the Euclidean distance between u and v in $\{X, Y, Z\}$ plane. In multi-hop wireless network, it is responsibility of routing protocols to find path between two end points through intermediate nodes. Traffic passes through intermediate nodes from source to destination, intermediate node act as a relay or forwarder. In our proposed protocol we have calculated path from each user to base station which is not much deviated from base station. This is particularly useful when a large number of nodes deployed in larger networks in a 3D plane and route is to be constructed from source to destination. In this paper, we have explained the proposed 3DMA routing protocol for 3D space based on minimum angle with distributed scheduling.

In the design of 3DMA routing protocol, first a reference line is drawn from sender/user/source to destination/base station/sink. Then a set of neighbor nodes are selected within the transmission range TR of the sender node. Suppose a user/sender node U has location (U_x, U_y, U_z) and another node N has location (N_x, N_y, N_z) in a 3 dimensional plane $\{X, Y, Z\}$, Node N will be in the neighbor set of node U, if Euclidean distance $\|UN\|$ between U and N is less or equal to the transmission range TR of U.

After that, selection of an intermediate node (IM) for forwarding or relay packets towards destination form selected neighbor list which makes minimum angle with the reference line drawn from source/user to destination/base station. Suppose sender/user node S has location (U_x, U_y, U_z), location of a neighbor node N is (N_x, N_y, N_z) and the location of the destination D is (D_x, D_y, D_z). For calculating angle $\measuredangle NUD$ i.e. θ formed by node N with the reference line drawn from U to D depends on two vectors, vector from source to destination, $\overrightarrow{\mathrm{UD}}$ and the vector from source to the node N itself, $\overrightarrow{\mathrm{UN}}$. The vector $\overrightarrow{\mathrm{UD}}$ is given by $(U_x - D_x, U_y - D_y, U_z - D_z)$ and $\overrightarrow{\mathrm{UN}}$ is given by $(U_x - N_x, U_x - N_y, U_x - N_z)$. Angle θ made by a node N from list of neighbor nodes, with the reference line drawn from sender U to destination D is calculated by the equation- 2 given bellow-

$$\theta = \cos^{-1}\left[\frac{\overrightarrow{\mathrm{UN}} \cdot \overrightarrow{\mathrm{UD}}}{\|\overrightarrow{\mathrm{UN}}\|\|\overrightarrow{\mathrm{UD}}\|}\right], \quad (2)$$

where $(\overrightarrow{\mathrm{UN}} \cdot \overrightarrow{\mathrm{UD}})$ is the dot product of $\overrightarrow{\mathrm{UN}}$ and $\overrightarrow{\mathrm{UD}}$, $\|\overrightarrow{\mathrm{UN}}\|$ and $\|\overrightarrow{\mathrm{UD}}\|$ is the euclidean vector norms [1]. Among all the neighbors the node that formed minimum angle with the reference line, is selected and used as forwarder towards destination. Now this node acts as a sender node, a reference line is drawn from this new sender node to the destination, then again minimum angle node is selected from neighbor list of this new sender node. Same procedure will be repeated for transferring the role of sender node to chosen intermediate node(IM), till it reaches the destination/ base station as an intermediate node and it will stop there.

Figure-1 describes clearly about 3DMA routing protocol, the nodes are defined by its three dimensional location information. We have considered here only one user/sender node and the range of a node is 25 to understand the protocol clearly. First a reference line (black lines is used in the Figure- 1 for representing the reference line from sender to destination) is drawn from user $U_1(0,50,50)$ to the base station $BS(45,60,0)$, U_1 finds set of neighbor nodes within its transmission range having location information $(0,50,40)$, $(10,50,35)$, $(17,60,35)$ and $(12,60,40)$, lines are drawn from sender to connect all these four neighbors (in Figure-1 blue lines are drawn for connecting sender with its neighbor nodes). Then angles with the reference line drawn from U_1 to BS for these four neighbor nodes are calculated, it is found that the node having location information $(10,50,35)$, we have named it as U_{11}, has formed minimum angle with the reference line, so node U_{11} is selected as next hop node/forwarder node towards the destination. We connect U_{11} with U_1 for showing the selected routing path (in Figure-1 red line is drawn for marking the finally selected routing path). Now U_{11} will act as the next sender node, like node U_1 a reference line is drawn from U_{11} to BS, neighbors of U_{11} within its transmission range are $(17,60,45)$, $(0,50,40)$, $(0,50,25)$and $(30,50,25)$, the neighbor node having location information $(30,50,25)$, named as U_{12} have made minimum angle with the reference line U_{11} to BS, therefore node U_{12} is the next forwarder node towards the destination. In the same way we have evaluated the proposed 3DMA routing protocol for the example network given in Figure- 1, we have found that the node having location information $(42,62,10)$, named as U_{13} among all neighbors of U_{12}, have formed minimum angle with the reference line drawn from U_{12} to BS; so node U_{13} is the next forwarder node towards destination (in Figure-1, U_{12} is connected with U_{13} with a red line for showing the selected routing path). Here in the example network shown in Figure-1, U_{13} is the last intermediate node to reach the final destination/base station BS, among the neighbors of U_{13}, the node having location information $(45,60,0)$, which is the base station(BS) have minimum angle $(0 \quad degree)$ with the reference line, this means final destination is reached, U_{13} and BS are joined with a red line and here it stops. The path calculated by the 3DMA routing protocol is $U_1 - U_{11} - U_{12} - U_{13} - BS$. It is clear from the Figure-1 that the packets reached at the base station/destination from sender through the minimum number of hops hence least delay, provides best possible link and improved end to end throughput. Path calculated by 3DMA is loop free.

A. Scheduling in 3DMA

In multi-hop wireless network due to interference caused by simultaneous transmission of nodes decrease the performance of network. Reason of interference between wireless devices is the broadcast nature of wireless communication[21]. Higher interference usually results in lower reliability of data transmission. To overcome this problem a Scheduling techniques is used. Packet scheduling is the process of allowing nodes in a network to receive or send packets so that there is no interference with other nodes in the network and maximize the system capacity, which is the most important radio resource management function in networks [21]. Scheduling is responsible to determine which packets are to be transmitted such that resources are fully utilized. In scheduling different links are activated at different time slots, for spatial reuse and higher spectral efficiency, transmission group may be formed for simultaneous transmission over group of links. In the proposed 3DMA routing protocol, at a given time, it is assumed that only one user has data to send to the base station or destination. Therefore only links in the route from that particular user to destination will be activated. If more than one user is ready to send data, then they need to take turn, one user at a time.

IV. Performance Evaluation and Result Discussion:

Performance of 3DMA routing protocol is evaluated by calculating end-to- end throughput and energy consumption, considering simulation parameters which are common for all nodes (as shown in table-I). All the nodes scattered in the network can be source or destination node, in 3DMA one of those scattered nodes is selected as a destination node and some of those as source nodes. We have considered a medium size network and find the route for number of senders to a destination. It is assumed that all nodes in the network knows the location information of itself, its neighbors and other nodes in the network using centralized location management system like GPS, or some other location management techniques or pre decided before deployment. For smaller transmission range we have divided X , Y and Z coordinate of each node in the network by 10.

TABLE I: Network simulation parameters

Network parameter	Value
Data packet size	1 MB
Network Area	$50 \times 60 \times 50$
Number of nodes	65 to 80
Range of node	2.5 Km
E_{elec}	50nJ/bit
E_{amp}	$100pJ/bit/m^2$
Number of Sender	6

In the 3DMA routing protocol for calculating throughput, we have assumed that nodes have burst profiles with modulation and coding rates to obtain different data rates with different transmission distance (as shown in table II).

Fig. 1. Routing path selection by 3DMA

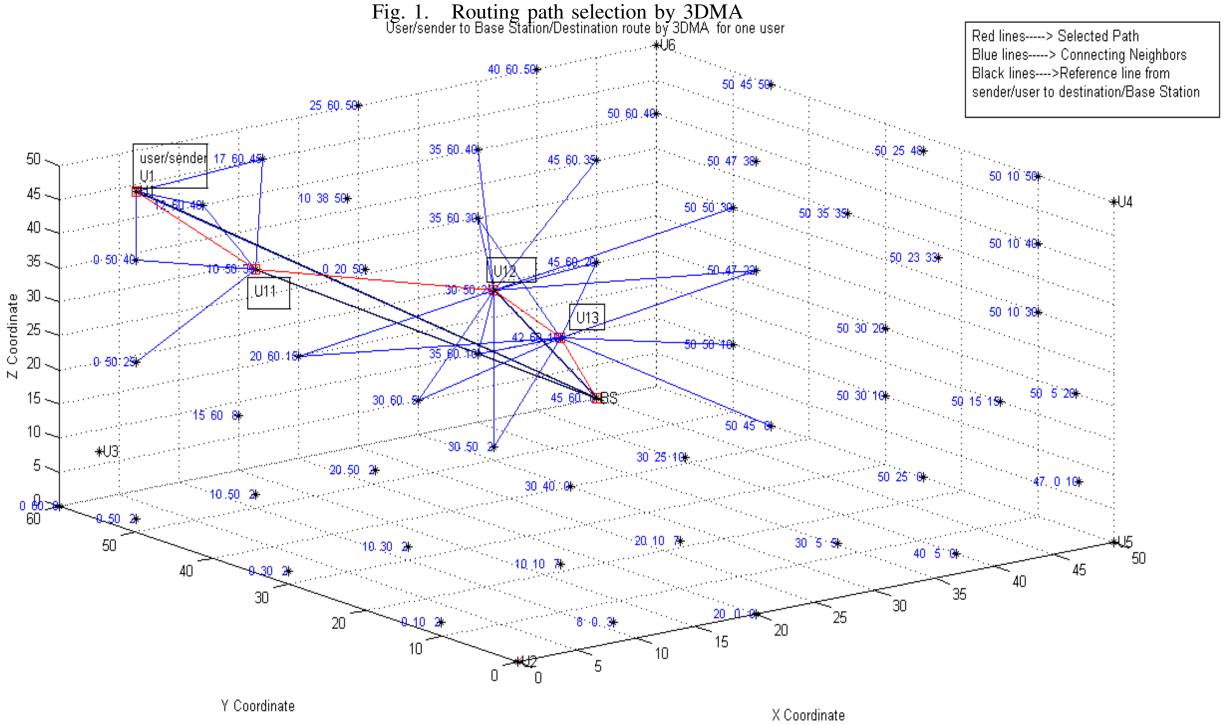

TABLE II: Bit rate and transmission ranges

Modulation	Coding Rate(C_rate)	Transmission Range(in Km)	Bit rates(B_rate) (in Mbps)
QPSK	1/2	$3.5 < l_i <= 5$	2
16-QAM	1/2	$2 < l_i <= 3.5$	5.5
64-QAM	3/4	$l_i <= 2$	11

Table-II shows that for different transmission ranges, different modulation and coding rates are used to obtain different bit rates. Smaller distance gives higher bit rate for data transmission. The 3DMA protocol calculates the time slot $T_i(sec)$ for transmitting data packet of size F (MB) in i^{th} link, having bit rate of a link B_rate (in Mbps) and coding rate C_rate by using the following equation-

$$T_i = \frac{(\frac{F}{C\_rate_i})}{B\_rate_i}, \tag{3}$$

end-to-end throughput ETH of a route from sender to destination is calculated using the equation- 4

$$ETH = \frac{F}{\sum_{i=1}^{pl} T_i}, \tag{4}$$

where pl is the number of links between source and destination i.e. the path length and T_i is the sum of times needed to travel each link in the routing path.
Throughput of the whole network is given by equation- 5

$$ETH_{3DMA} = \sum_{j=1}^{U_n} (\frac{F}{\sum_{i=1}^{pl} T_i}), \tag{5}$$

where U_n is the number of user or sender in the network.

Energy consumption is another important issue in multi-hop wireless networks, specially in multi-hop wireless sensor networks. The 3DMA protocol calculates energy consumption of each node for transmitting and receiving packets. For a receiver node energy consumption per bit in RF module[9] is calculated using the following equation 6

$$E_{rec}(k) = E_{elec} \cdot k, \tag{6}$$

where E_{elec} is the energy required to process 1 bit of message and k is the length of the message in bit.
Energy consumed by the transmitter in RF module[9] is calculated using equation 7

$$E_{trans}(k, d) = E_{elec} \cdot k + E_{amp} \cdot k \cdot d^2, \tag{7}$$

where d is the distance between sender and receiver in meter. E_{elec} is energy required to process 1 bit , E_{amp} is the energy required to transmit 1 bit (nJ Nano-joule, pJ Peta-joule), and k is the length of the message (in bit).

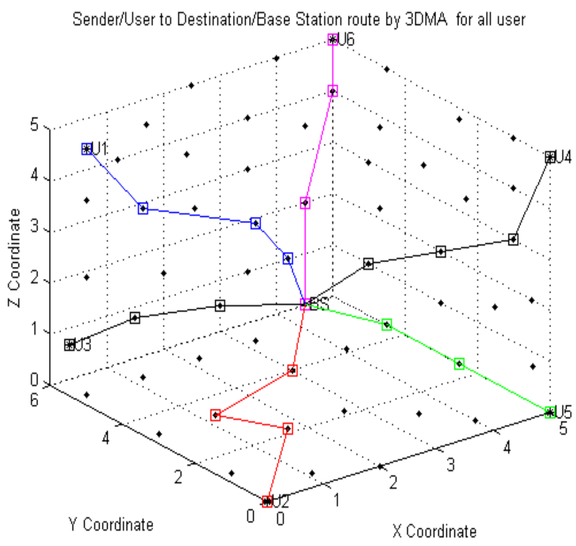

Fig. 2. The First Network

TABLE III: Performance Analysis of first Network shown in Figure-2

Sender	ETH (Mbps)	No. of IM	Time(Sec)	Energy (Joule)
Sender1	1.0313	3	0.9697	1.12×10^{28}
Sender2	0.8250	3	1.2121	1.44×10^{28}
Sender3	2.7500	2	0.3636	0.53×10^{28}
Sender4	0.8250	3	1.2121	1.38×10^{28}
Sender5	1.6500	2	0.6061	1.20×10^{28}
Sender6	1.6500	2	0.6061	0.74×10^{28}

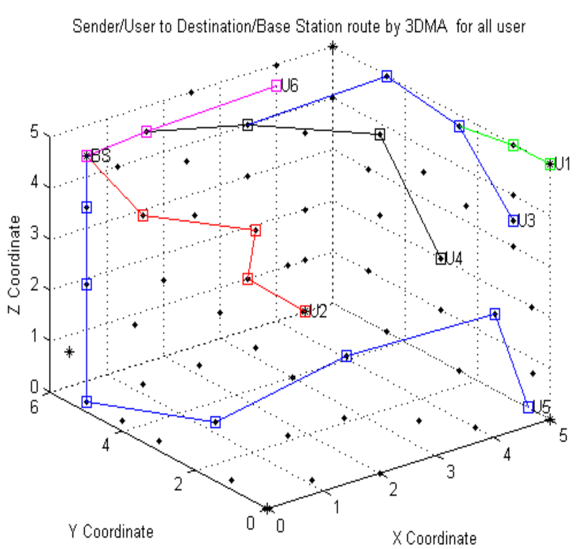

Fig. 3. The Second Network

TABLE IV: Performance Analysis of Second Network shown in Figure-3

Sender	ETH (Mbps)	$No.$ of IM	Time(Sec)	Energy (Joule)
Sender1	0.6875	5	1.4545	1.64×10^{28}
Sender2	1.3750	3	1.7273	1.10×10^{28}
Sender3	0.7500	4	1.3333	1.69×10^{28}
Sender4	1.0313	3	0.9697	1.42×10^{28}
Sender5	.5500	6	1.8181	2.14×10^{28}
Sender6	1.3750	1	0.7273	0.76×10^{28}

Figure-2, Figure-3, Figure-4 and Figure-5 are showing the routing path for data transmission by 3DMA routing protocol from 6 senders/users $U1$, $U2$, $U3$, $U4$, $U5$ and $U6$ to base station/destination. In the first network, sender nodes are placed on the edges in other side of network and base station is placed in the center of the network. In 2nd and 3dr networks the base station is placed in one edge and senders are placed in the others edges of the network. Table-III, table-IV, table-V and table-VI are tabulated, the end-to-end throughput for each user, number of intermediate nodes in the routing path between source and destination, total time needed to travel data packets from source to destination, total energy consumption for each sender to transmit data packets to destination.

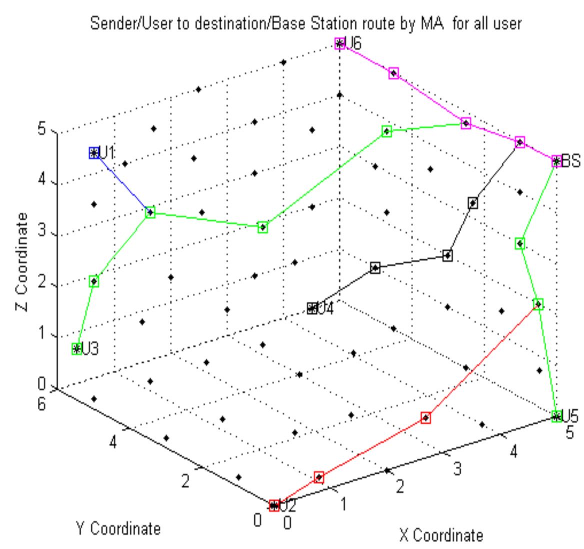

Fig. 4. The Third Network

TABLE V: Performance Analysis of Third Network shown in Figure-4

Sender	ETH (Mbps)	$No.$	Time(Sec)	Energy (Joule)
Sender1	0.6875	5	1.4545	1.86×10^{28}
Sender2	0.7500	4	1.3333	1.47×10^{28}
Sender3	0.6346	6	1.5758	2.04×10^{28}
Sender4	.9167	3	1.0909	1.20×10^{28}
Sender5	1.7686	2	.8485	0.84×10^{28}
Sender6	1.3750	3	0.7273	0.77×10^{28}

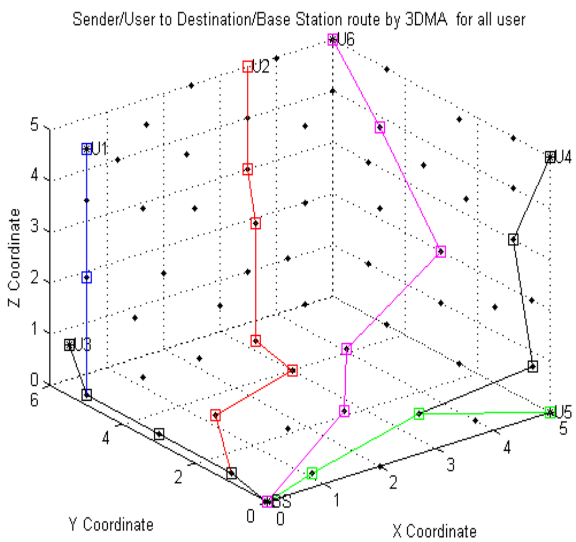

Fig. 5. The Fourth Network

TABLE VI: Performance Analysis of Fourth Network shown in Figure-5

Sender	ETH (Mbps)	*No.*	Time(Sec)	Energy (Joule)
Sender1	0.9167	4	1.0909	1.65×10^{28}
Sender2	0.6347	6	1.5758	1.83×10^{28}
Sender3	2.0627	3	0.4848	0.81×10^{28}
Sender4	.7500	4	1.3333	1.55×10^{28}
Sender5	1.1786	2	0.8485	0.83×10^{28}
Sender6	0.7500	4	1.3333	1.87×10^{28}

From table-III, IV,V and VI, it is observed that, if the link distance between two nodes in the routing path is less, it takes less time for sending data packets between nodes, so it increases the throughput. When distance between sender and destination is long and distance between intermediate nodes are also reasonably long in routing path, then it takes more time to reach the destination, which in turn reduces the end-to end throughput and increases the energy consumption for transmitting data packets. The performance analysis tables shows that if throughput increases then it decrease the energy consumption. If the link distance between two nodes is more, then more energy is needed to transmit the data packets between them. [1]

V. Conclusion and Future Work

In this paper, we have proposed a simple 3 dimensional routing protocol (3DMA) for multi-hop wireless networks, intermediate nodes towards destination are chosen based on the angle which is minimum among all the angles formed by the lines from sender to its neighbors and the reference line from sender to destination. We have calculated efficient routing path for each sender to destination, which takes minimum number of hops to reach the destination, considering that at a time one user node has data to send. Performance of the 3DMA routing protocol is evaluated by calculating, time, end-to-end throughput and energy consumption for each user. After analysis the results we have observed that if distance between two node in the routing path is long then it decreases the throughput and increases the energy consumption for transmitting packets i.e. if throughput increases then amount of energy needed to transmit data packets decreases. The proposed 3DMA routing protocol is loop free. In future work our focus will be on developing efficient scheduling techniques so that at a time more than one user can send data without any interference, considering node mobility of the nodes in network.

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References

[1] 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.

[2] Shitai Bao, Ningchuan Xiao, Zehui Lai, Heyuan Zhang, and Changjoo Kim. Optimizing watchtower locations for forest fire monitoring using location models. *Fire Safety Journal*, 71:100–109, 2015.

[3] Kechar Bouabdellah, Houache Noureddine, and Sekhri Larbi. Using wireless sensor networks for reliable forest fires detection. *Procedia Computer Science*, 19:794–801, 2013.

[4] Ismail Butun, Salvatore D Morgera, and Ravi Sankar. A survey of intrusion detection systems in wireless sensor networks. *IEEE communications surveys & tutorials*, 16(1):266–282, 2014.

[5] Jan Chudzikiewicz, Janusz Furtak, and Zbigniew Zielinski. Secure protocol for wireless communication within internet of military things. In *Internet of Things (WF-IoT), 2015 IEEE 2nd World Forum on*, pages 508–513. IEEE, 2015.

[6] Rodolfo WL Coutinho, Azzedine Boukerche, Luiz FM Vieira, and Antonio AF Loureiro. Gedar: geographic and opportunistic routing protocol with depth adjustment for mobile underwater sensor networks. In *Communications (ICC), 2014 IEEE International Conference on*, pages 251–256. IEEE, 2014.

[7] Rodolfo WL Coutinho, Azzedine Boukerche, Luiz FM Vieira, and Antonio AF Loureiro. Geographic and opportunistic routing for underwater sensor networks. *IEEE Transactions on Computers*, 65(2):548–561, 2016.

[8] Gopal Dommety and Raj Jain. Potential networking applications of global positioning systems (gps). *arXiv preprint cs/9809079*, 1998.

[9] 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.

[10] 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.

[11] 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.

[12] 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.

[13] 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.

[1] Sender,user,source are used synonymously and the base station and destination are used synonymously.

[14] Abhishek Joshi, Sarang Dhongdi, Rishabh Sethunathan, Pritish Nahar, and KR Anupama. Energy efficient clustering based network protocol stack for 3d airborne monitoring system. *Journal of Computer Networks and Communications*, 2017, 2017.

[15] Abdullah Kadri, Elias Yaacoub, Mohammed Mushtaha, and Adnan Abu-Dayya. Wireless sensor network for real-time air pollution monitoring. In *Communications, Signal Processing, and their Applications (ICCSPA), 2013 1st International Conference on*, pages 1–5. IEEE, 2013.

[16] Elis Kulla, Shinji Sakamoto, Makoto Ikeda, and Leonard Barolli. Manet approaches for airborne networks: a survey. In *Network-Based Information Systems (NBiS), 2013 16th International Conference on*, pages 66–70. IEEE, 2013.

[17] Zonglin Li, Nianmin Yao, and Qin Gao. Relative distance based forwarding protocol for underwater wireless networks. *International Journal of Distributed Sensor Networks*, 10(2):173089, 2014.

[18] Youngtae Noh, Uichin Lee, Paul Wang, Brian Sung Chul Choi, and Mario Gerla. Vapr: void-aware pressure routing for underwater sensor networks. *IEEE Transactions on Mobile Computing*, 12(5):895–908, 2013.

[19] Bushra Rashid and Mubashir Husain Rehmani. Applications of wireless sensor networks for urban areas: A survey. *Journal of Network and Computer Applications*, 60:192–219, 2016.

[20] 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.

[21] Tsung-Yu Tsai, Yao-Liang Chung, and Zsehong Tsai. *Introduction to packet scheduling algorithms for communication networks*. Sciyo, 2010.

[22] Yu Wang, Chih-Wei Yi, Minsu Huang, and Fan Li. Three-dimensional greedy routing in large-scale random wireless sensor networks. *Ad Hoc Networks*, 11(4):1331–1344, 2013.

[23] 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.

[24] 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.