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Relay node selection algorithm consuming minimum power of MIMO integrated MANET

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Abstract. Establishment of an efficient routing technique in multiple-input-multiple-output (MIMO) based mobile ad hoc network (MANET) is a new challenge in wireless communication system to communicate in a complex terrain where permanent infrastructure network implementation is not possible. Due to limited power of mobile nodes, a minimum power consumed routing (MPCR) algorithm is developed which is an integration of cooperative transmission process. This algorithm select relay node and support short distance communication. The performance analysis of proposed routing algorithm increased signal to noise interference ratio (SNIR) resulting effect of cooperative transmission. Finally performance analysis of the proposed algorithm is verified with simulated result.

Keywords: MIMO; MANET; propagation loss; signal strength; routing

1. Introduction

Advancement in communication system enables MANET to broadcast information packets in any hazardous environment. MIMO technology with multiple antenna elements serves a number of users' equipment simultaneously which share mutual resources. One of the efficient methods of transmitting packets from source to destination receiver node in MANET is broadcasting, and designing an efficient broadcasting protocol is the most demanding task in MIMO integrated mobile ad hoc networks. Mobility, dynamic topology and resource sharing are the unique characteristics of MIMO integrated MANET. The mobility of these nodes changes the network topology dynamically causing frequent path failures. Packet broadcasting of MIMO implemented MANET is mainly done in resource sharing mechanism. Limited radio range of mobile nodes necessitate multihop transmission in the integrated network to establish communication, and packets transmitted from the valid mobile source node may not reach the target node in a single hop but by multiple hops through some intermediate node called relay node. Selection of intermediate node is an important criterion as these nodes use the valuable resources of the

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network like battery power and bandwidth etc (Liu *et al.* 2007, Mohammad *et al.* 2009, Majid *et al.* 2016). Packet forwarding to the entire mobile network, paging of a node, network management, route discovery, and overhead control is served by this broadcasting method (Shah *et al.* 2014, Nosratinia *et al.* 2013). Different broadcasting technique has been proposed and studied by many researchers of which performance analysis of conventional routing protocol is done (Manickam *et al.* 2011, Jabbari *et al.* 2016) considering single hop and multi hop routing. Taksande *et al*. (2011) compared the performance of protocols in NS-2 simulation environment and indicated improvement. Discrete optimal sizing of truss using adaptive directional differential evolution and simulation of small link conventional routing in OPNET environment is done (Anh *et al*. 2016, Vats *et al*. 2012). Comparison of performance of single-hop and multihop routing followed by simulation is done for ordinary ad hoc network (Karthik *et al.* 2012, Peruma *et al.* 2015). Topology and geometry optimization using ECBO is done (Kaveh *et al.* 2016, Abdelaziz *et al.* 2017). A hybrid routing protocol is analyzed where distance, metric value and node failure is considered (Kaur 2013, Raheja *et al.* 2014, Wang *et al.* 2017). Selection of relay node for routing process based on coding cooperative approach and real time channel state approach is described (Xu 2014, Medeiros *et al.* 2017). In coding cooperative approach, authors describe the basic idea that each user must transmit increasing redundant information for cooperative partner and the basic principle of real time channel state approach is to transmit real time channel information of source node to relay node and relay to destination node. The best partner selection algorithm using stable matching concept is discussed (Hasan *et al.* 2013). Here authors focused on 'selective' decode-forward transmission where relay station only decodes the data and retransmit the data to the destination. From the review work we find most of the routing algorithm is developed on basis of distance, metric value and node failure. Development of this proposed algorithm is based on selection of best suitable relay node. The best suitable relay nodes selection process is done considering the parameters propagation loss and probability of collision during transmission, which gives most effective transmission power. This effective transmission power makes up the proposed hybrid routing algorithm in different terrain presented in this paper. We propose a routing protocol considering all these parameters in an energy efficient way.

The rest of this paper is organized as follows. In Section 2 defined rationality of relay node. Section 3 described selection of relay node followed by proposed MPCR algorithm in section 4. Section 5 shows simulation results and discussion. Finally, Section 6 summarizes the main findings of this work.

2. Rationality of relay node

Conventional flooding mechanism has some limitation due to the limited power of mobile nodes, more interference, and fading effect. A pragmatic alternative will be to replace a single long range link by a chain of short range links connecting series of intermediate nodes between source and destination. The intermediate node receives the signal from the source, processes and retransmits to the next node of the chain. The intermediate nodes are known as a relay node and by multiple hoping through relay nodes, the packet reaches the destination node. Relay node provides seamless communication even if a node becomes partially inefficient due to the effects such as energy depletion, node failures and interaction with the hostile environment. As interference is less in relay communication the signal to interference ratio will be higher over long range communication. Higher throughput may be achieved by multihop transmission over direct communication if the numbers of hops are optimized.

3. Criteria for selection of relay node

A novel method of selection of relay node is proposed here. The nodes that are being considered here are randomly distributed in a complex terrain and simplicity of calculation having a uniform sensitivity (S), which is defined as minimum received signal strength (RSS_{min}) necessary to generate adequate usable power output in presence of noise. The received signal strength at any node from the parent node will be affected due to propagation loss multipath fading and loss of packet information due to collision over multichannel interference. The variation of signal strength at any distant point due to the combined effect of propagation loss and multipath fading will have spatial and temporal variations. The nature of spatial variations of received signal strength is shown in Fig. 1.

The continuous fluctuation of the signal strength may have ping-pong effect at the receiving node. To avoid ping-pong effect we select the node to consider for relay where the average value of the received signal strength is little more than the sensitivity of the mobile node S. The value of the signal strength is proposed as Th, which is ΔS above the sensitivity of the mobile node called threshold level, as shown in Figure 1. If the received signal strength of any node is less than the threshold level then the particular node will not be considered as a relay node. Let P_c be the probability of collision due to multichannel interference, then (1-P_c) will be the probability of successful transmission (P_s) in a particular terrain.

From the above consideration, we find that for selection of suitable relay node, there are two important points needed to be considered: (i) Received signal strength should be above the threshold that is $P_r \geq P_{th}$ and (ii) Probability of collision should be minimum that is $P_c \leq x$. We define a term P_e as the effective received power for a successful reception at the particular node, which is product of P_r and P_s. Thus the criteria for selection of relay node is (i) received signal should be more than the threshold value (P_{th}) and (ii) probability of collision should be less than x ($0 \leq x \leq 1$).

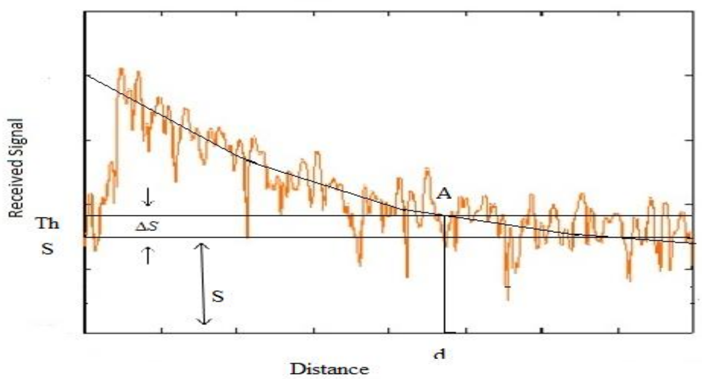


Fig. 1 Variation of received signal strength

That means

$$\left(1-P_c\right)*P_r \geq \left(1-x\right)*P_{th} \quad (1)$$

where $P_r \geq P_{th}$; $P_c \leq x$

The number of nodes in the ad hoc network between source and destination, which satisfy the above condition (shown in Eq. (1)) may be considered as relay nodes for transmission. Now for a particular case where more than one node is satisfying the above condition, then the particular node is selected as first stage relay node where RSS is minimum (minimum received signal strength can optimize the hop distance) and if RSS value of two nodes is same then we select the relay node where (1-P_c) is maximum. Second phase relay node is selected considering first phase relay node as a source node and the process of hopping through relay nodes will be continued till the information reaches final destination node.

3.1 Estimation of propagation loss

Propagation loss (P_L) for MIMO integrated MANET in different terrain is already been calculated (Chowdhuri *et al.* 2016), which is shown in subsequent section. Let, $PL_{1\text{-}2}$ be the Propagation Loss between the nodes with multiple antennas which are placed in forest area, $PL_{2\text{-}3}$ - Two nodes with multiple antennas are in plane earth (outdoor propagation loss) propagation environment, $PL_{3\text{-}4}$-One ad hoc node with multiple antennas in outside the building and another ad hoc node with multiple antennas is inside the building, $PL_{4\text{-}5}$ - Two ad hoc nodes with multiple antennas inside the building and $PL_{5\text{-}6}$= Two ad hoc nodes with multiple antennas is within the building in different floor, these are formed as

$$PL_{1-2} = -10\log_{10}\left(\frac{1}{MN}\sum_{f}\sum_{i=1}^{M}\sum_{j=1}^{N}\left\{\left[H_{i,j}\right]^{T}*\left[I\right]_{N*1}\right\}\times\frac{d^4 d_0^2}{R^2 f^2}\right) \quad (2)$$

where d-forested depth in meter, R-radius of ad hoc nodes, d_0-distance between two ad hoc nodes, f-frequency of the operating signal.

$$PL_{2-3} = -10\log_{10}\left(\frac{1}{MN}\sum_{f}\sum_{i=1}^{M}\sum_{j=1}^{N}\left\{\left[H_{i,j}\right]^{T}*\left[I\right]_{N*1}\right\}*\left(Q*A_r\right)\right) \quad (3)$$

$$\left(Q*A_r\right) = \left(\frac{1}{2}\frac{e^2}{120\pi}\right)*\left(\frac{\lambda^2 g_r}{4\pi d_r}\right) \quad (4)$$

where e - Electric field strength

$$PL_{3-4} = -10\log_{10}\left(\frac{1}{MN}\sum_{f}\sum_{i=1}^{M}\sum_{j=1}^{N}\left\{\left[H_{i,j}\right]^{T}*\left[I\right]_{N*1}\right\}*\left(Q\times A_r\right)\right)+\left[-10\log_{10}\left(\frac{1}{MN}\sum_{f}\sum_{i=1}^{M}\sum_{j=1}^{N}\left\{\left[H_{i,j}\right]^{T}*\left[I\right]_{N*1}\right\}*\left\{L_f F^{K_1} W^{K_2} R\right\}\right)\right] \quad (5)$$

where F - Floor loss (For same floor the value of floor loss will be 2 to 3),W - Wall loss, R - Reflection loss, K_1 - Number of floor, K_2 - Number of wall

$$PL_{4-5} = -10\log_{10}\left(\frac{1}{MN}\sum_{f}\sum_{i=1}^{M}\sum_{j=1}^{N}\left\{\left[H_{i,j}\right]^{T}*\left[I\right]_{N*1}\right\}\times\left\{L_f F^{K_1} W^{K_2} R\right\}\right) \quad (6)$$

$$PL_{5-6} = \left[-10\log_{10}\left(\frac{1}{MN}\sum_{f}\sum_{i=1}^{M}\sum_{j=1}^{N}\left\{\left[H_{i,j}\right]^{T}*\left[I\right]_{N*1}\right\}\times\left\{L_f F^{K_1} W^{K_2} R\right\}\right)\right] \quad (7)$$

Subtracting propagation loss from transmitted signal the effective received signal strength can be easily estimated. Now packet loss due to the probability of collision (P_C) is needed to calculate for selection of relay node.

3.2 Estimation of probability of successful transmission

Let us consider of model of transmission process via relay node shown in Fig. 2. In the model diagram source node *S* transmit data to destination node *D* via relay node *R*. h_{sr}, h_{sd}, h_{rd} are the channel gain of the source to relay, source to destination and relay to the destination node. Transmit signal power is $P_S^{'}$ and received signal power $P_r^{'}$. We know that the transmission probability of any channel depends on channel capacity of the channel. Channel capacity of any channel is the maximum value of mutual information. So, to estimate the probability of transmission first action is to calculate mutual information of the channel. Mutual information of cooperative communication in amplify-and-forward method is (Zhang *et al.* 2009) found as

$$I_{SD}^{AF} = \log\left(1 + P_s^{'}\left|h_{sd}\right|^2 + \frac{P_s^{'}\left|h_{sr}\right|^2 P_r^{'}\left|h_{rd}\right|^2}{1 + P_s^{'}\left|h_{sr}\right|^2 + P_r^{'}\left|h_{rd}\right|^2}\right) \tag{8}$$

In our work, we consider MIMO integrated mobile ad hoc network, so it is needed to estimate mutual information of MIMO channel. Mutual information of amplify-and-forward method for MIMO channel is (calculated in appendix I)

$$\left(I_{SD}^{AF}\right)_{MIMO} = \log\left(1 + P_s^{'}\sum_i\sum_j\left|h_{sd}^{ij}\right|^2 + \frac{P_s^{'}\sum_i\sum_j\left|h_{sr}^{ij}\right|^2 P_r^{'}\sum_i\sum_j\left|h_{rd}^{ij}\right|^2}{1 + P_s^{'}\sum_i\sum_j\left|h_{sr}^{ij}\right|^2 + P_r^{'}\sum_i\sum_j\left|h_{rd}^{ij}\right|^2}\right) \tag{9}$$

where $i(1,2,..M)$ and $j(1,2,\ldots N)$ signify a number of transmitting and receiving antennas. Channel capacity of the MIMO channel using amplify-and-forward method is

$$(C_{AF})_{MIMO} = \max\left(I_{SD}^{AF}\right) \tag{10}$$

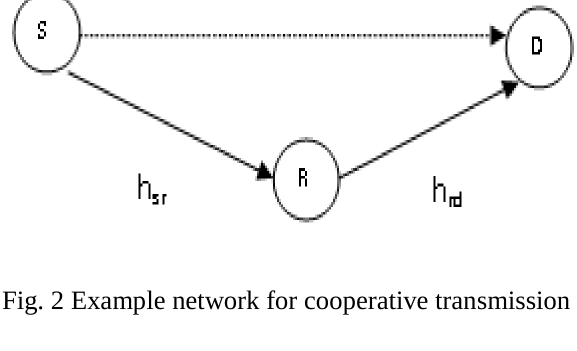


Fig. 2 Example network for cooperative transmission

To estimate probability density function we need to study the SNIR of the received signal as CDF function depends on SNIR. SNIR of the threshold value (β) of any channel is found by inverting the capacity function $\beta \propto C^{-1}$ [16]. β is used to generate Cumulative Distributive Function (CDF) (Torrieri *et al.* 2012). From this, the estimation of Probability Density Function (PDF) of the received signal is done which become

$$f_{y_i}(y) = (1 - p_i)\delta(y) + p_i\left(\frac{n_i}{\omega_i}\right)^{n_i} \frac{1}{\Gamma(n_i)} y^{n_i - 1} e^{-y n_i / \omega_i} u(y) \quad (11)$$

Where p_i is the active probability of a particular node n_i.

$$\text{Signal at receiving end } y=[\, y_1, y_{2,} y_{3,} \ldots y_n \,] \quad (12)$$

Probability of successful transmission

$$P_S = \int_0^n f_{y_i}(y)dy \quad (13)$$

$$\text{Probability of collision } P_c = 1 - P_s \quad (14)$$

Intermediate relay node estimated on basis of propagation loss and the probability of successful transmission.

3.3 The steps followed for the selection of relay nodes are as follows:

Step1: Estimating received signal strength (P_r) and probability of successful transmission (P_s).

Step2: Define a threshold value (P_{th}) slightly just above sensitivity of the node and probability of collision (x) where $0 \le x \le 1$.

Step3: Check the condition for selection of relay node is, (effective received signal strength)

$$P_s * P_r \ge (1 - x) * P_{th} \quad (15)$$

Step4: If the condition is satisfies then the node is considered as relay node where effective received signal strength is minimal. For same value of minimum effective received signal strength, the particular node is selected as relay node where probability of successful transmission is maximal. If in some cases more than one node meets all the above condition then any one of the nodes can be selected as a relay node.

4. Proposed MPCR algorithm

In the proposed algorithm, the best partner (suitable relay node) selection routing (optimized path) is decided on the basis of received power (P_r) by the node (estimated in section 4.1) and probability of successful transmission (P_s) (estimated in section 4.2). In the model network shown in Fig. 4, 20 numbers of MIMO integrated ad hoc nodes are randomly distributed in a combined terrain. Any ad hoc node first broadcast the route update to its neighbors periodically. Each neighboring node that receives the updates for the first time rebroadcasts the update and marks the node from which it receives recursively till every node in the network has rebroadcast the update once and find its parent. In this way, the routing table for effective power (P_e), multiplication of received power (P_r) by the node and probability of successful transmission (P_s), is updated in a periodic way. From this routing table of the source node, we compare the total power of the entire surrounding node within its transmission range. Finally select the best relay partner node where a total loss is minimal. In this way, first phase relay node selection is done and then this node becomes the source node for selection of next phase relay selection. Again the path loss is compared in the same way except at the parent node (from where the source receives the data) and the next relay node is selected with minimum loss route. This process repeats and updates the routing table until it reaches the destination. In the above figure, source node 1 transmits the packet to its neighbors within its transmission range. Node 4, 6 and 16 are within the transmission range of source node 1. The source node floods the data to its neighbor's nodes and checks which node satisfies the condition for equation (1). If any node does not satisfy the condition then this node is not considered for the relay node selection process. In this case node 4, 6 and 16 satisfy the condition of equation (1) so all three nodes can be considered as relay nodes. Within all these nodes, received signal strength of nodes 6 and 16 is minimum so that particular node is considered as a relay where the probability of successful transmission is maximum (node 16 satisfy all these conditions), here node 16 is selected as first stage relay node. In the second stage node 16 acts as a source node and transmit signal to all the nodes 3, 5 and 14 which are within transmission range but except its parent node 1 to find the second phase relay node. The process continues until transmitted signal reaches the final destination node 10. In this algorithm, the flooding node will not be considered as receiving node so that back propagation is prohibited.

5. Simulation result and discussion

This section presents the simulation results in MATLAB environment to validate the proposed routing algorithm. In this paper, a model network with 20 numbers of nodes has been considered in different terrain (forest, free space and indoor).

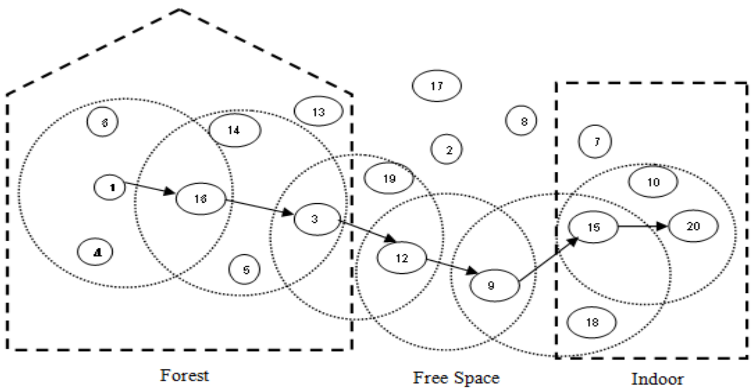
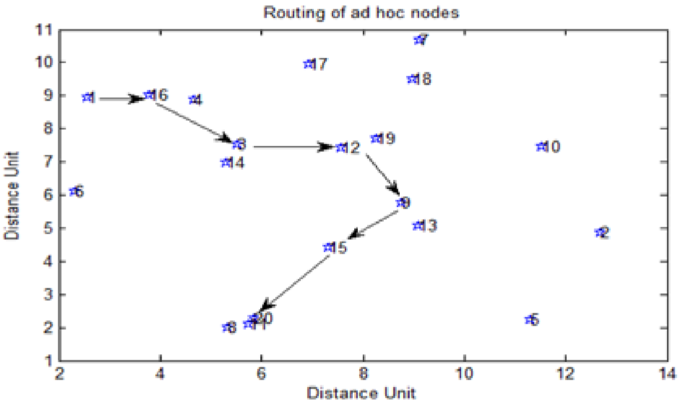
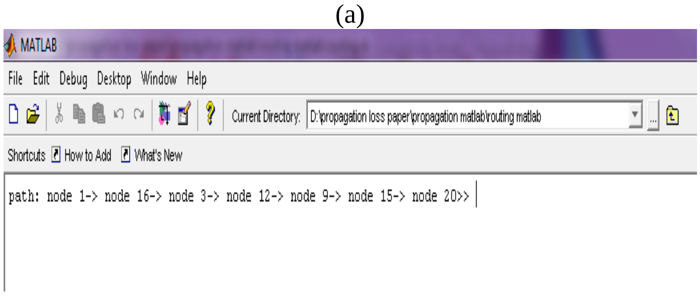


Fig. 3 Proposed network for verification of algorithm



(a)



(b)

Fig. 4 (a) Simulated route of the network and (b) Simulated route of the network

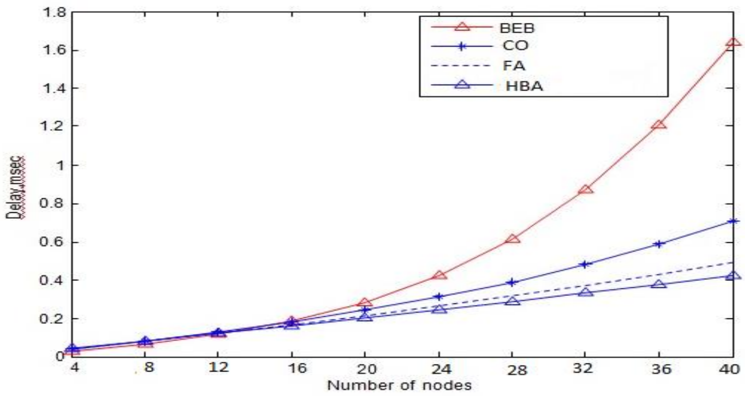


Fig. 5 Nodes vs Transmission delay at different broadcast algorithm

The propagation loss and packet loss due to the probability of successful transmission are calculated for all nodes in different terrain. The route using MPCR algorithm is shown in Figs. 4(a) and 4(b). The best route is: **node1->node16->node3->node12->node9->node15->node20**. Fig. 5 depicts a comparative study of this hybrid algorithm with other existing algorithm. It is found that the transmission delay is reduces for this hybrid algorithm which makes the transmission faster.

6. Conclusions

MPCR algorithm provides seamless communication as the signal to noise interference ratio is much more due to short range communication. From the performance analysis it may be shown that proposed algorithm works very efficiently in complex terrain. Study of performance of the proposed algorithm provides higher transmission rate multihop transmission over direct communication. The proposed an MPCR algorithm is based on the cooperative transmission. Cooperation of transmission is done by selecting best suitable relay node. The relay node is selected on basis of effecting received signal strength of mobile ad hoc node and probability of successful transmission. Consideration of the relay node makes short distance communication which can improve the SNR. The proposed algorithm may be noted that out-performs most of the existing algorithm presently in use.

References

Abdelaziz, H. and Tizani, W. (2017), “Evaluation of current practice and associated challenges towards integrated design”, *Adv. Comput. Des.*, **2**(2), 89-105.

Anh, H.P. (2016), “Discrete optimal sizing of truss using adaptive directional differential evolution”, *Adv. Comput. Des.*, **3**(1), 275-296.

Chowdhuri, S., Chaudhury, S. and Banerjee, P. (2016), “Propagation analysis of hybrid model of MIMO ad hoc network and implement less propagation loss algorithm to find the minimum loss route”, *Int. J. Inform. Commun. Technol.*, **10**(1),66-80.

Hasan, C., Altman, E. and Gorce, J (2013), “Partner selection for decode –and-forward cooperative relaying: a matching theoretic approach”, *Proceedings of the IEEE 24th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications*.

Jabbari, M., Ghayour, M. and Reza, H. (2016), “Increasing the performance of energy harvesting in vibration mode shapes”, *Adv. Comput. Des..*, **1**(2), 155-173.

Karthik, S., Kannan, S., Valarmathi, M., Arunachalam, V. and Ravichandran, T. (2012), “A performance analysis and comparison of multi-hop wireless ad-hoc network routing protocols in MANET”, *Int. J. Academic Res.*, **2**(4), 36-41.

Kaur, S. (2013), “Performance evaluation of hybrid routing protocols in mobile ad hoc network”, *Int. J. Adv. Res. Comput. Sci. Software Eng.*, **3**(9), 634-640.

Kaveh, A. and Rezaei, M. (2016), “Topology and geometry optimization of different types of domes using ECBO”, *Adv. Comput. Des.*, **1**(1), 1-25.

Liu, H., Jai, X., Wan, J., Liu, X. and Yao, F. (2007), “A distributed and efficient flooding scheme using 1-hop information in mobile ad hoc networks”, *IEEE T. Parall. Distr. Syst.*, **18**(5), 658-671.

Majid, J., Mostafa, G. and Hamid, R.M. (2016), “Increasing the performance of energy harvesting in vibration mode shapes”, *Adv. Comput. Des.*, **1**(2), 155-173.

Manickam, P., GuruBaskar, P., Girija, M. and Manimegalai, D. (2011), “Performance comparisons of routing protocols in mobile Ad hoc networks”, *Int. J. Wireless & Mobile Netw*., **3**(1), 98-106.

Medeiros, G. and Kripka, M. (2017), “Modified harmony search and its application to cost minimization of RC columns”, *Adv. Comput. Des*., **2**(1), 1-13.

Mohammad, A. and Mikki, W. (2009), “Energy efficient location aided routing protocol for wireless MANETs”, *Int. J. Comput. Sci. Inform. Security*, **4**(1), 1-2.

Nosratinia, A. and Hedayat, A. (2013), “Cooperative communication in wireless networks”, *IEEE International Symposium on Personal Indoor and Mobile Radio Communications*, 2275-2280.

Perumal, M. and Dhandapani, S. (2015), "Modeling and simulation of a novel relay node based secure routing protocol using multiple mobile sinks for wireless sensor networks", *The Scientific World J.*, **2015(**Article ID 495945), 1-9.

Raheja, K. and Maakar, S. (2014), "A survey on different hybrid routing protocols of MANET", *Int. J. Comput. Sci. Inform. Technol.*, **5**(4), 5512-5516.

Shah, S. and Islam, S. (2014), "A survey on cooperative communication in wireless networks", *Int. J. Intel. Syst. Appl.*, 7(1), 66-78.

Taksande, V. and Kulat, D. (2011), "Performance comparison of DSDV, DSR, AODV protocol with IEEE 802.11MAC for chain topology for a mobile ad-hoc network using NS-2", *Int. J. Comput. Appl.*, **6**(3), 26-31.

Torrieri, D. and Valenti, M. (2012), "The outage probability of a finite ad hoc network in Nagagami fading", *IEEE Commun. Soc.*, article id 1207.711, 1-9.

Vats, K., Sachdeva, M., Saluja, K. and Rathee, A. (2012), "Simulation and performance analysis of OLSR routing protocol using OPNET", *Int. J. Adv. Res. Comput. Sci. Softw. Eng.*, **2**(2), 1-4.

Wang, J., Shucai, L. and Liping, L. (2017), "Collapse risk evaluation method on Baysian network prediction model and engineering application", *Adv. Comput. Des.*, 2(2), 121-131.

Xu, S. and Wang, F. (2013), "Analysis and comparison of relay node selection algorithm of cooperative communication", *Inform. Technol. J.*, **12**(3), 434-438.

Zhang, P., Yuan, J., Chen, J., Wang, J. and Yang, J. (2009), "Analyzing amplify-and-forward and decode-and-forward cooperative strategies in Wyner's channel model", *IEEE wireless communication and networking conference*, NJ, USA, April.

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