

# OTP: OPTIMAL DATA TRANSMISSION PATH ALGORITHM TO DISCOVER ENERGY EFFICIENT ROUTES IN MOBILE AD-HOC NETWORKS

<sup>1</sup>SivaKumar.S, <sup>2</sup>Chellatamilan.T. and <sup>3</sup>Muthumanickam.K.

<sup>1</sup>Assistant Professor, Department of Electronics and Communication Engineering,

<sup>2,3</sup>Professor, Department of Computer Science and Engineering,

<sup>1,2,3</sup>Arunai Engineering College, Tiruvannamalai, Tamilnadu, India

<sup>1</sup>sivakumar\_aec@yahoo.com, <sup>2</sup>chellatamilan\_t@yahoo.com, <sup>3</sup>kmuthoo@yahoo.com

## Abstract:

*Mobile Ad-hoc Network (MANET) is a kind of wireless network that consists of self-configuring mobile nodes which can communicate using wireless links. As mobile nodes can freely move in and out of a MANET, its topology structure can also change over time, i.e. can't have fixed topological structure as wired networks. This causes many problems like link failure, redundant links, etc. Introducing relay nodes to avoid link failure can't be an ideal solution. Therefore, a novel algorithm to select Optimal Transmission Path (OTP) algorithm in a MANET has been proposed. The proposed OTP algorithm discovers an energy efficient route from source mobile node to the destination mobile node and also minimizes hop count and delay. This method mainly relies on the transmission- and receiving power of each node for efficient node selection in the current network. This protocol reduces the average transmission redundancy and enhances the packet delivery ratio. Simulations results points out that the proposed OTP algorithm attains better delivery ratio and also improve the energy of the network.*

**Keywords:** Mobile ad-hoc Network, Energy Efficiency, Optimal path, Dynamic topology.

## 1. Introduction

A MANET is a cluster of wireless nodes forming an instant network. The formation of such a network has no wires, no centralized base station and infrastructure and even does not require administrative intervention [11]. All nodes in a MANET have excellent sensing power, transmitting power and receiving power and can route packets to all its intermediate nodes in the network [8]. Among various existing network architectures, a MANET has magnetized lot of consideration in different real time applications where wired network failed to setup. Typically, MANETs have no centralized device to control functions such as data transmission, forwarding, congestion control, etc. These constraints create routing a challenging problem in MANETs. In this environment each node includes all function to

forward data or control packets to the next immediate hop permitting them to reach the destination node through multiple hops.

An addition each node may operate as router, source node, destination node and can move unreservedly in any direction and thus making rapid and irregular topology. The nodes in a MANET are often battery powered through a great assortment in their ability, thus conserving an individual node's power and energy is a crucial design problem and also becoming a challenging issue.

The nodes that recline within each other's communication range can do communication directly and also responsible for dynamically learn each other. However, to permit communication between nodes which don't fall within each other's radio coverage can use intermediate nodes. The important problems like energy consumption and transmission band become the root cause for node disconnection and rerouting. This problem can be resolved thorough multi-hop communication technique where source node can send data packets to its communicating node using intermediate nodes. However, a node requires more energy to communicate its destination node which is located too far. The communication range is directly propositional to the energy requirement of a node. However, a MANET encounters larger hop count to make data transmission complete.

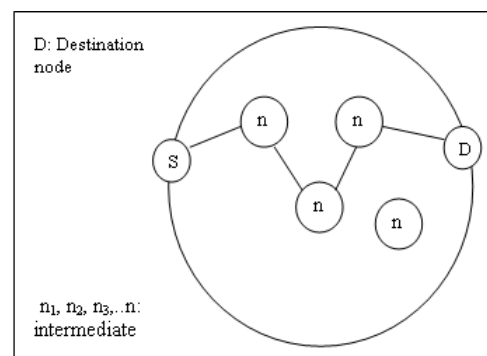


Fig. 1(a) Route formation at time T between S and D

Recently, implementing wireless based applications becomes a timely requirement and also popular. There were many routing discovery protocols for MANETs exist which have proposed by researchers in the past. However, performance of a MANET becomes a crucial part of its design. This is because of its dynamic topological changes. Even, movement or disconnection of a single mobile node in a pre-established path increases route complexity problem, thereby affecting the performance of the whole network. Though, passive routing protocol like AODV handles node disconnectivity problem by implementing route discovery mechanism, restarting the same path many times causes problems like redundant paths and nodes as shown in Fig. 1.

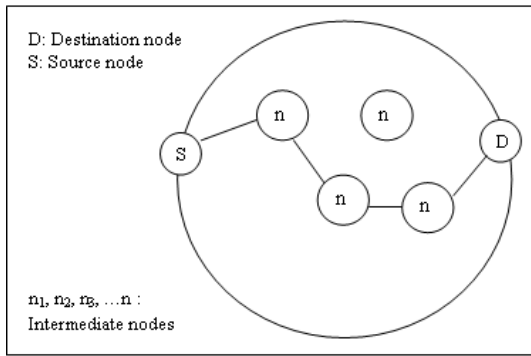


Fig. 1(b) Route formation at time  $(T+ t)$  between S and D

To address the aforementioned problems, we propose an Optimal Transmission Path (OTP) discovery algorithm to conserve power and energy of mobile nodes, thus lengthening the life time of the current network is possible. An intermediate node is selected by OTP algorithm based on its current energy level and relative angle.

The rest of this paper is segmented as follows: Sect. 2 describes the various existing papers related to the discovery of optimal routes in MANETs. The OTP algorithm for improving energy efficient optimal path among mobile nodes in a MANET is proposed in Sect. 3. Performance analysis and comparative performance are shown in section 4. Conclusion part is described in section 5.

## 2. Related works

There are few serious research works have been carried out for MANETs with different aspects like routing, power control and energy management, and security implementations, and so forth. The basic goal in a MANET is the ability to work in multi-hops, thus intermediate mobile nodes taking the responsibility of forwarding packets to the intended destination node. Thus, trust worthiness and

cooperation between intermediate mobile nodes is becomes an important issue. In specific, establishing energy aware routing may become the vital design criteria of a MANET, this is because mobile nodes are battery powered and limited capacity. Power letdown of a mobile node in a MANET not only has effect on the mobile node itself but failed to forward the packets on behalf of other nodes and hence reduce the overall life time of the entire network. Therefore many researchers have been focused on developing energy efficient routing protocols.

The traditional routing protocol, AODV performs better when the time required to set up a MANET is small [12]. One of the noted features of AODV is offering better packet delivery ration compared to DSR protocol. There exist different energy optimal route discovery mechanisms for MANETs [14-15]. Specifically, the distinguished character for the classification is the time for performing optimization process. A mobile node in a MANET not only consumes energy when sending or transmitting data packets but also during listening to the medium. Therefore, researchers focused on minimizing energy of a node wither during active transmission process or inactive listening period in MANET.

### A. Reviewing Heinzelma et al. 's Algorithm

Heinzelman et al. [1] presented an algorithm namely LEACH to discover an efficient routing path which requires low energy for MANETs. The LEACH algorithm is performed in many stages in which each stage consists of two important steps: a setting up step which represents the initial event of the step and an exploring step that represents the last task of the step. During the setting up stage, the underlying network forms the cluster which forms nodes with similar properties. After a steady state is reached, a cluster member forwards the data packet to the base station which is then responsible to forward the received packet to the destination.

In order to elect the Cluster Head (CH) node, the presented LEACH algorithm determines its probability of selection. A Cluster Member (CM) who wants to act as cluster head is assigned with probability 0 and the probability for other nodes is determined by Equation.

$$P_x(t) = \begin{cases} \frac{k}{N - K(r \bmod \frac{n}{k})} & C_i(t) = 1 \\ 0 & C_i(t) = 0 \end{cases} \quad (1)$$

Where  $n$  denotes the total number nodes reside in the current network,  $k$  refers the total number clusters formed and  $r$  represents the total number of rounds performed. In addition  $C_i(t)$  denotes the CH node that wants to perform. Any CM node who wants to transmit data during its own time window used time division multiple access scheme. All other times, the CM nodes sit idle; thus energy is saved and life time of the current network is extended. However, we found two critical issues: first, as the CH node is responsible to forward a data packets received from a member node, it should always be awake. Second, some time the cluster heads which reside outside transmission area require more energy.

#### B. Reviewing Younis et al.'s Algorithm

The algorithm presented in [2] namely, energy efficient hybrid distributed (EEHD) algorithm relies on the density of the current network to offer energy efficient data transmission. The cluster head node is selected based on its probability using the energy level of the other nodes. The probability of selection of the CH node is calculated using Equation.

$$CHP = C_P \times \frac{E_{residual}}{E_{max}} \quad (2)$$

Where  $C_P$  denotes the constant value of the probability,  $E_{residual}$  represents the residual energy of node, and  $E_{max}$  refers to the maximum energy level of the node. The EEHD algorithm the cluster members nodes to select the CH node using the probability and calculates the minimum reachability power required using the Equation.

$$R = \frac{\sum_{i=1}^n MinPow_i}{M} \quad (3)$$

Where  $MinPow_i$  refers to the minimal energy required when a cluster member  $i$  sends data to the CH node and  $M$  denotes the total number of CMs reside in its transmission range. Any node that becomes a CH node should have minimal  $R$  value. At time  $t$ , any CM can compare its  $R$  value against  $R$  value of the current CH node and may become the CH node if its  $R$  value is small.

#### C. Reviewing of RODMRP Algorithm

The dynamic multicast routing algorithm discussed in [3] is suitable for inference network and relies on network changes. RODMRP algorithm

establishes the communication path and more importantly manages the current network based on clustering technique. In addition, RODMRP uses two step procedure to setup the routing path: Local discovery routing and flooding discovery routing. The former approach uses a step parent for setting and managing family of groups. The latter approach floods the message to all its immediate neighbor and repeat this process until a complete path is established.

#### D. Reviewing Lowest Identification Clustering Algorithm

The Lowest Identification Clustering (LIC) formed a cluster (with CH and CM) using the unique  $id$  value of each node in the network. The CH node is selected with lowest  $id$  value and compares its  $id$  value against each CM node. If a node's  $id$  value is greater than the  $id$  value of the CH node, then it becomes the CM. Sometimes a node may reside within the transmission range of two CH nodes, and then routing is performed with the help of gateway nodes. However, such a communication path may often disconnect and also consumes more energy [4].

#### E. Reviewing Mobility based metric clustering algorithm

The mobility based metric clustering algorithm (MOBICA) is designed to form clusters based on speed of the CH node in MANETs. To form a cluster, MOBICA uses the interval time for transmitting a hello message and speed of a node which is inferred using its coordination values. The node with low speed is then selected as the CH node. Afterwards, the CH node permits other nodes to become its CM. Even though MOBICA performance better, communication between two nodes is disconnected and the network structure changes often.

#### F. Reviewing Minimum Energy Routing Protocol (MERP)

In order to estimate the information like node cost and link cost, the following problems need to be resolved. (a) method to obtain precise information about power level of a node (b) overhead caused during discovery of energy sensitive routing path and (c) technique to maintain a route with minimum energy during mobility. The MER protocol [5] overcomes the aforementioned by integrating power control tuning schemes in DSR [6] and MAC protocol [7] with eight different modifications as shown in Table 1.

Table 1 Modification adopted in MERP

| Modifications                                  | Comment  |
|--|----------|
| i: Routing packets based on power control      | Software |
| ii: Low energy routing path                    | Firmware |
| iii: Cache replies off                         | Software |
| iv: Internal cache timeout                     | Software |
| v: Multi hops route establishment              | Software |
| vi: Transmission of ACK based on power control | Firmware |
| vii: Route maintenance based on power sensing  | Software |
| viii: Mechanism of DATA/ACK snooping           | Firmware |

To estimate the required power by the sender node to transmit a packet, Option (i) alters the header information of a route-request control packet. This information is then used by the receiver node along with radio transmit power level to infer minimal power needed for successfully completing data transmission. The power information is temporarily stored at all intermediate nodes towards the destination node and the destination node notifies the source node through route-reply control packet. Whenever the source nodes want to communicate with the destination node, it appends the power information in the packer header field, thus the routing path might used minimal power for successful transmission. The same process is also applied for transmission of MAC layer ACK control packets.

Options (ii), (iii) and (iv) are associated with route-cache mechanism of DSR routing protocol. Option (ii) is mainly used to determine the path with minimum power requirement. If the sender node has more routing paths to the same destination node, then using option (i), the sender determines single optimal path. Option (vii) adjusts the low energy routing paths when the necessary power level changes due to mobility of nodes. Options (iii) and (viii) permit a non-member node to snoop on transmission and inform the sender node and MAC layer about the energy efficiency of the route.

An energy efficient scheduling algorithm E-COPS [13] relies on establishing shortest optimal route between the source node and the destination node using multiple hops, if necessary.

The shortest energy optimal path is selected based on relative angle of a node. Though E-COPS performs better than LIC algorithm and MOBIC algorithm, our proposed OTP algorithm selects an

intermediate hop only if it's available energy is greater.

### 3. Proposed OTP Algorithm

The main goal of this sub-phase of the research work is to develop an effective algorithm to select an optimal multicast routing algorithm in MANETs using power energy level of each intermediate node from source to destination. Recently, implementing wireless based applications has become a timely requirement and also popular. There were many routing protocols for MANETs exist which are proposed by researchers in the past. However, the performance of a MANET becomes a crucial part of its design. This is because of its dynamic topological changes. Even, movement or disconnection of a single mobile node in a pre-established path increases route complexity problem, thereby affecting the performance of the whole network. Though, a passive routing protocol like AODV handles the node disconnectivity problem by implementing route discovery mechanism, restarting the same path many times causes problems like redundant paths and nodes.

The proposed OTPA algorithm makes use of power energy measurement equation modified first order ratio model [9] by using Equation (4) and modified optimal route selection algorithm [10].

$$E_T(b, h) = E_{T-ep}^{2b}(b) + E_{T-amp}(b, h) \quad (4)$$

Where,  $E_T(b, h)$  is the power energy consumption while a source node transmits databit/packet,  $h$  represents the distance between two nodes, which is measured in terms of hop counts, and  $b$  represents the data bits/packet.

The power energy consumption is measured as the sum of  $E_{ep}^{2b}$  and  $amp(b, h)$  i.e. the energy required for transmitting a single bit data by covering the distance 'h'. The power energy to be consumed mainly depends on  $E_{amp}(b, h)$  for covering distance 'h' than  $E_{ep}^{2b(b)}$ . In short, the factor 'h' between any two nodes becomes a crucial factor that decides the energy efficiency of the current network.

The OTPA algorithm mainly uses the energy and radio reception power of each node while selecting an intermediate node. Each node maintains different information as listed in Table 2.

**Table 2** Packet Information in as MANET

| OTPA                  |
|-----------------------|
| Packet Information    |
| Source                |
| Destination           |
| Sequence number       |
| Power energy level    |
| Radio reception power |
| Pre_hop               |
| Post_hop              |
| TTL                   |

As each node maintains various important information such as transmit power level and radio reception power, selecting an optimal routing for data transmission really increases the lifetime of the current topology. The proposed OTPA algorithm works as described below.

1. First, the source mobile node that desires to transmit data to its communicating node selects an intermediate mobile node based on relative angle and distance.
2. It is achieved by estimating the distance from the source node to a base station that decides the radio reception power of that node.
3. To establish an optimal path, the source node opts many intermediate healthy-powered nodes; thereby increasing the coverage distance.

The source node increases the transmission coverage area by checking whether an intermediate node is energy powered or not. The power energy level of a node is measured using the Equation (5).

$$RE = AE - [EC_T + EC_R] \quad (5)$$

Where,  $AE$  represents the available power energy of a node,  $EC_T$  and  $EC_R$  represents the energy consumed to complete data transmission and reception respectively. If any intermediate node has  $RE$  greater than 90 percent, then the node is selected to form optimal path. Otherwise, the current node selects next immediate neighbor node based on its relative angle which is calculated using Equation (6).

$$Inode_{ij}^r = \{0 < Inode_{ij}^r \leq \Pi\} \quad (6)$$

Accordingly, the optimal path is established while a source node transmits a packet to the base

station. The nodes of the established path leverage power and energy efficiency to increase the current topology lifetime. The proposed OTP algorithm chooses suitable intermediate node based on relative angle as shown in Figure 2.

In order to establish an energy efficient routing path, the OTP algorithm an intermediate node which locates nearer to it (i.e. shorter distance,  $d$ ) and largest relative angle ( $r$ ). The underlying network cannot always maintain balanced transmission state. When the data is being sent from source to destination through unbalanced distribution, the CH node needs to cover a larger distance to reach the base station; thus the energy conservation of CH node is increased. However, the proposed OTP algorithm increases current network life time by converting the unbalanced distribution into balanced distribution. Therefore, minimizing the energy conservation of each node during data transmission.

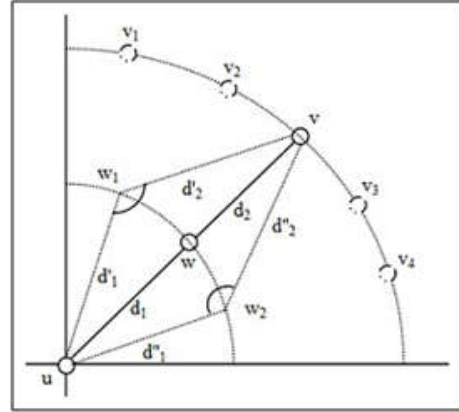


Fig. 2. Selection of an intermediate node using OTPA

The OTP algorithm chooses the number of intermediate hops  $k$ , by balancing the distance between all its immediate neighboring nodes. The current routing path from the source node that wants to send data packets to the destination node must forward it to the based station is stated in Equation 7.

$$RP = \{CH_i, CH_{(i+1)}, \dots, CH_{(i+k)}, i = 1\} \quad (7)$$

Where  $RP$  represents the temporary path established between the source node and the base station,  $CH$  denotes the cluster head node and  $k$  represents the number of intermediate hops. Table 2 depicts the algorithm for determining and selecting a power energized intermediate node. If the  $RE$  of an intermediate node is greater than 0.5 then the transmitting node assumes that the selected intermediate node is not balanced. Thus, the source node increase the coverage area by adding more intermediate hops based on its relative angle.

Table 2 Pseudo code to detect the first power energized intermediate node

|   |
|---|
| <b>Procedure:</b> OTP Algorithm   |
| <b>Input:</b> Source node (S) and Destination (d)                               |
| <b>Output:</b> Optimal route R  |
| <b>begin</b>  |
| $r \leftarrow \emptyset$  |
| $Inode_{sd}^r \leftarrow 0$   |
| healthy $h \leftarrow 0$  |
| $h[] \leftarrow$ intermediate nodes from S towards D                            |
| $n \leftarrow$ intermediate nodes $h[]$ from S towards D                        |
| $L \leftarrow 0$  |
| temp $d_{sd}^r \leftarrow 0$  |
| $R \leftarrow R \cup S$   |
| <b>while</b> ( $L \leq n$ ) {   |
| <b>if</b> ( $Inode_{sd}^r$ is powered enough) <b>then</b>                       |
| $h \leftarrow h[L]$   |
| <b>else</b> {   |
| $Inode_{sd}^r \leftarrow \text{determineangle}(s,d)$                            |
| <b>if</b> ( $Inode_{sd}^r \leq \pi/2$ )   |
| $d_{sd}^r \leftarrow \sqrt{d_{sr}^2 + d_{rd}^2 + 2d_{sr}d_{rd} \cos(d_{sd}^r)}$ |
| <b>elseif</b> ( $Inode_{sd}^r \geq \pi/2$ )                                     |
| $d_{sd}^r \leftarrow \sqrt{d_{sr}^2 + d_{rd}^2 - 2d_{sr}d_{rd} \cos(d_{sd}^r)}$ |
| }   |
| $h \leftarrow h[L]$   |
| <b>end</b>  |
| $R \leftarrow R \cup h$   |
| $R \leftarrow R \cup d$   |
| <b>end</b>  |

As depicted in Table 3, to select an optimal energy efficient path/route, the source mobile node

checks the power energy of the first intermediate mobile node. If the power energy of that node is high (greater than 90 percent), the source node extends its coverage distance with next node by applying the same procedure. When the power energy is lower than the predefined value, then the source node determines its relative angle to discover an energy efficient intermediate node. This process is repeated until a stable and optimal path is discovered.

#### 4. Performance evaluations

In this section, we present the procedure for the simulation of proposed OTP algorithm using Network Simulator, NS2. OTP algorithm is simulated in a scenario to evaluate its performance and efficiency in the network with different count of nodes that are installed randomly. The simulation is performed in wireless environment using the network size of 2000\*2000m. The performance of the OTP algorithm is compared with algorithms like MOBICA, LICA, and ECOPS by transmitting data packets through the established path.

Table 1 Simulation parameters

| Parameter              | Value            |
|------------------------|------------------|
| Simulation Time        | 60s              |
| # Nodes                | 200              |
| Routing Protocol       | EERPH and LMST   |
| Simulation Area        | 1000x800         |
| Transmission Range     | 250              |
| Antenna Type           | Omni Antenna     |
| Network Interface Type | Wireless PHY     |
| Channel Type           | Wireless Channel |

The simulation results validated the performance of the OTP algorithm based on two important aspects: energy consumption and packet delivery ratio. Figure 3 shows the portion of simulation network in which the current network comprises of several nodes which randomly appear in different locations and they can freely move in and out of the network. In addition, the central controller i.e. base station pretends to be one of the nodes appears in the middle. When a CM wants to transmit data to the destination node then the CH node receives the data and forwards it to the BS, if and only if the BS resides within the radio transmission range. When the BS resides outside the radio transmission range then the Ch uses multiple intermediate hops o reach the BS.

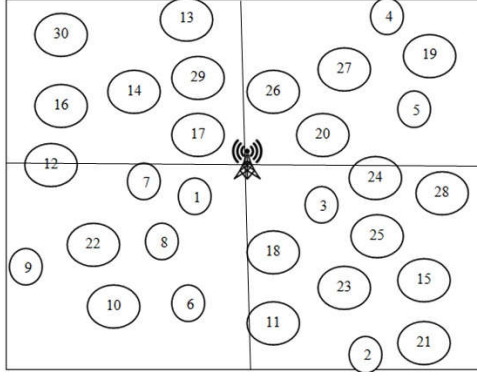


Fig. 3 Portion of the network environment

### A. Energy maintenance

There were 500-1000 rounds used in the simulation against MOBICA, LIC, E-COPS and OTP algorithms. The E-COPS algorithms retains more rounds then MOBIC and LIC algorithms. As the proposed OTP algorithm discovers a suitable intermediate node based on its energy and relative angle, the energy preservation is minimal than the E-COPS algorithm as shown in Figure 4.

### B. Packet delivery ratio

The packet delivery ratio (PDR) of the proposed OTP algorithm based on the transmission range is depicted in Figure 5. As the radio transmission distance increases, both the MOBIC and LIC algorithms maintain the PDR between 31- 40 %. Our OTP algorithm and E-COPS algorithm improves the packet delivery ratio than other two algorithms. But E-COPS algorithm maintains PDR between 82-88%.

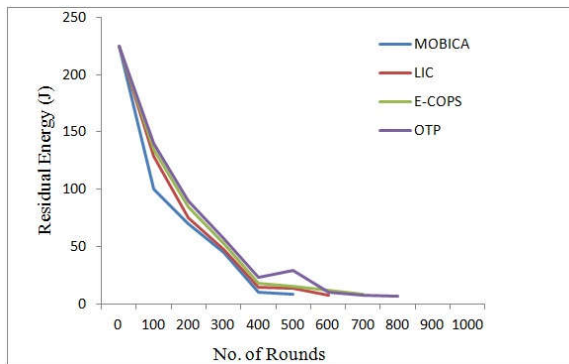


Figure 4 Residual energy Vs rounds

Compare to all other algorithms, the proposed OTP algorithm maintains better packet delivery ratio and when the coverage area is amplified, the OTP algorithm improves the packet delivery rate with 93%.

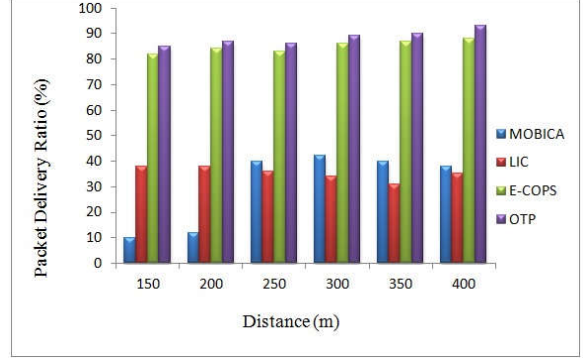


Figure 5 PDR Vs radio coverage area

## 5. Conclusion

In this research article, we proposed OTP algorithm for establishing energy efficient optimal path in a MANET. The CM node that sender wants to transmit data packet to its communicating node should forward it to the CH node which is responsible to forward the packet to the base station. If both the base station and CH node don not lie in the same transmission range, then the CH node might chooses multiple intermediate hops. The proposed OTP algorithm discovers an optimal path based on the relative angle and energy availability of each next hop. The proposed OTP routing algorithm increases the lifetime of the current network through discovering optimal energy efficient shortest path.

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