PATH DISCOVERY AND SELECTION FOR ENERGY EFFICIENT ROUTING WITH TRANSMIT POWER CONTROL IN MANET

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ABSTRACT

Main aim of the work is to design an energy efficient routing mechanism based on Dynamic Source Routing (DSR). In order to achieve energy efficient reliable transmission, routing here is divided into two parts. One is to discover the path based on Received Signal Strength (RSS) and residual energy and the other is to select based on minimum energy consumption. By eliminating the nodes that has low RSS value in transmission, path breakages can be avoided. Discovering the path based on residual energy results in the reduction of node failure. Selecting the path that consumes less energy extends the network lifetime. The prediction of RSS for path discovery under mobility will make the transmission reliable. The proposed work called Path Discovery and Selection for Energy Efficient Routing (PDSEER) is designed in such a way that when DSR starts the route discovery after checking its route cache , the required transmit power is set first inorder to save energy. Then RSS of the RREQ and node's remaining energy is validated for deciding whether a node can forward the RREQ or not. The data is transmitted after selecting the path that consumes minimum energy. Simulation results are compared for overhead, packet delivery ratio, energy consumption, number of path breakages and delay. The analysis reveals that the proposed system is energy efficient compared to basic DSR, PAMP, SSBR and MTPCR.

Keywords: Energy consumption, received signal strength, reliable transmission, trasmit power control and network lifetime

1.0 INTRODUCTION

A mobile ad hoc network (MANET) is comprised of self organizing mobile hosts that can communicate with each other using wireless links in an arbitrary manner. The main application areas are in emergency disaster relief personnel coordinating efforts after a natural disaster such as a hurricane, earthquake, or flooding, and military personnel relaying tactical and other types of information in a battlefield. The major problem with MANET is that it depends on batteries for power. These are multi hop in nature and in most of the cases; the destination node is out of transmission range of the source node. The intermediate mobile nodes will act as routers [23] and help the source node to communicate with the destination. An important challenge in the design of algorithms for this network lies in the fact that its topology is dynamic, thereby affecting the availability of routing paths. Hence, designing a routing protocol that finds a path which is reliable and less energy consuming in order to achieve high throughput and lifetime is a challenging one.

Energy-aware routing schemes were analyzed in [1, 7, 17, 19, 20, 28] to prolong the lifetime of nodes in wireless ad-hoc networks. Dynamic networks are provided with multi-hop functionality by some on demand routing protocols. The reactive routing protocols, for example Dynamic Source Routing (DSR) [15, 16] and Ad-hoc On-demand Distance Vector (AODV) [5] finds the path for data transfer in order to reduce the transmission time, delay and the number of path breakages. But this will definitely ends up in an increase in the average length of hops. This is not really acceptable in real scenario. If the number of path breakages is more, then there is an increase in distance between hops in a routing path. So, to avoid this, path discovery mechanism based on Received Signal Strength (RSS) and residual energy is found to be a suitable choice. Finding a reliable path for the data transfer results in good packet delivery ratio and throughput with a reduction in energy consumption.

Energy consumption can also be obtained by transmit power control algorithms. The effect of transmission power control on the consumed energy was detailed in [10, 21]. To consume less energy for packet transmission

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to their neighbours, nodes reduce their transmission power. Network capacity [11, 18] can also be increased by reducing the transmission power of nodes. Hence, it is decided to control the transmit power before the path discovery process in the proposed system. It is done by considering the two factors RSS and residual energy. When a Route REQuest (RREQ) is forwarded to the neighbours by the source node, neighbour nodes after receiving the RREQ, it checks received RSS value for finding whether the forwarding nodes are nearer or not. Then the residual energy of the node is validated based on a threshold and selected for broadcasting the RREQ. Link breakages can be determined based on the RSS value provided the interference is assumed to be negligible [3]. However, if nodes can adjust their transmission power (knowing the location of their neighbours), then the constant metric can be replaced by a power metric that depends on distance between nodes [12, 22, 27]. The distance between neighbouring nodes can be estimated on the basis of incoming signal strengths and the relative coordinates can be obtained by exchanging such information between neighbours [3].

Based on the results given in [24], the distance between two nodes affects the transmission power. The relationship between energy and distance is expressed as in Eq. (1) as,

$$u(d) = \varepsilon d^{\alpha} + c \qquad (1)$$

Where $u(d)$ represents power consumption, d is the distance, ε is a coefficient that depends on physical environment, and the unit size of a signal, c and α are constants. Where α varies between 2 and 4. From Eq. (1), it can be seen that if the distance increases, energy consumption also increases which implies that the RSS is low. Therefore, in a MANET, distance based on RSS has to be updated quite often in order to improve the connectivity of the network. When the mobility is high, there will be more link breakages and the network will be flooded with more RREQs [25, 26]. This results in low throughput and high packet failure ratio. In order to further enhance the system, path selection is carried out.

Most common property of the reactive routing protocols is that they discover routes using broadcast flooding by transmitting at maximum power in order to minimize the number of relay nodes between source and destination. The proposed design is based on DSR protocol. The drawback of AODV is that the average distance between hops in the found path may be too long, resulting in bad transmission bandwidth and an increased likelihood of path breakage [6].

In [9], the authors proved that the inefficiency of the routing in MANET is based on broadcast flooding techniques. They claimed that the generation of many signaling packets at lower transmission power is the reason for flooding. The intermediate forwarding nodes in the discovered routes were also maximum. Based on all these, it is understood that routing protocols do not provide an optimal power aware routes for MANET. Therefore, cross layer framework is chosen to enhance the performance of the system in terms of energy consumption and lifetime. The physical layer parameter is made to be available for the upper layers for discovering the path. We assume that the number of paths discovered will be always more than that of the number of paths selected for transmission. In this paper, we propose a mechanism called Path Discovery and Selection for Energy Efficient Routing (PDSEER). It concentrates on the RSS value and residual energy for discovering the routes and minimum energy consumption paths for the data transmission.

The rest of this paper is organized as follows. Related works on power aware routing protocols and the basic DSR are discussed in the second section. Section three describes the proposed energy efficient routing protocol. Section four gives the results and performance analysis of the proposed work. Results are compared with DSR, Power - Aware Multi-Path Routing (PAMP), Signal Strength Based Routing (SSBR) and Minimum Transmission Power Consumption Routing (MTPCR) in terms of packet delivery ratio, energy consumption and number of path breakages. The last section gives the conclusion of the work.

2.0 RELATED WORKS

Increasing the life time of mobile adhoc networks by minimising energy consumption has been analysed by many researchers. Most of them minimize the energy consumed to transmit or receive packets. Each work has its own merits and demerits. Therefore, in the proposed work, path discovery is done first concentrating on RSS value and node's residual energy. Then path selection is carried out. An overview of the classical on demand routing protocol namely DSR, PAMP, SSBR and MTPCR are discussed below.

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2.1 Dynamic Source Routing

When a node wants to communicate with another node, it first checks its route cache. If no route is found, the sender finds a route using the route discovery process. For finding a path for the transfer, a source node broadcasts a RREQ packet to all neighbouring nodes within its radio transmission. RREQ packet contains the addresses of the source, destination nodes, and a route record which contains a list of nodes visited by the RREQ packet. When a node which is not the destination, receives the RREQ, it records the related information and rebroadcast it. Instead, when a destination node receives the RREQ, it replies with a RREP (Route REPly) packet to the source along the path. The traversed paths are recorded by the source node. Among all the traced paths, DSR dynamically selects one path to transmit data. And also It finds the path with the minimum number of hops. The DSR is designed specifically for use in multi-hop mobile ad-hoc networks. Due to the mobility of the nodes, topology is changing quite often. It does not use periodic 'hello' messages. DSR operates in promiscuous listening mode. So, at any time, the node can check its route cache for the desired routes. In DSR, route discovery and maintenance each operate entirely "on demand". Hence, DSR is said to be an on - demand routing protocol. Overhearing improves the network performance by allowing nodes to collect more route information. But, it could make the situation even worse by generating more RREP packets for a route discovery to offer alternative routes. While the primary route is checked for its validity during the communication between the source and the destination, alternative routes may remain in route cache unchecked even after they become stale.

2.2 Power-Aware Multi-Path Routing Protocol

In PAMP [30], authors assumed that the source node knows the amount of power consumed in transmitting a data. Here, the destination node after receiving the first RREQ, the power availability in the path is found and based on this, the amount of data transmitted is calculated. This is done so to check whether the power available is enough to complete the data transmission or not. If the power is insufficient to complete data transmission, then the destination node waits for the later RREQs to determine a suitable path for data transfer after verifying all paths. Then, it sends back the RREPs of all the recorded paths to the source node. If there is a path breakage during data transmission, PAMP selects another path, this enhances the uninterrupted communication. One problem arises in this during high mobility is that the transmission bandwidth of the alternative paths may get reduced and this causes more power to be consumed. PAMP was applicable to the situation in which data transmission can not be completed with only one path. Since PAMP allows a node to process multiple RREQs for a session, it incurs more RREQs in the network comparatively. The multiple paths leads transmission bandwidth reduction.

2.3 Signal Strength Based Routing for Power Saving in Mobile Ad-hoc Networks

The transmission bandwidth between two nodes is taken for designing SSBR. In [6], authors have proposed a bandwidth based power-aware routing protocol that reduces power consumption and prolongs network lifetime. They measured the distance between two nodes based on the received signal strength, without using a Global Positioning System (GPS). Transmission bandwidth is determined by using the dB-to-bandwidth table. When the node receives the RREQ, the values of RSS and broadcast time are recorded and it is sent to the source node as RREP packet for selecting the path. The RSS variations are used to predict the possible amount of data that can be transmitted via a link. This is also used to find the remaining power of nodes in the path after the data transmission is over. The average transmission bandwidth, number of rerouting paths, path lifetime, power consumed when a byte is transmitted, and network lifetime (ratio of active nodes) are considered for comparison. The authors proved with simulation results that SSBR has achieved a reduction in the power consumption for data transmission and an increase in the network lifetime by taking bandwidth, path lifetime, and remaining power into consideration.

2.4 Minimum Transmission Power Consumption Routing

In MTPCR [5], they have concluded that selecting a path that has a high transmission bandwidth can reduce

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power consumption and shorten the delay during data transmission. The approach concentrated on the two factors that influence the transmission bandwidth: the signal strength of the received packets and contentions in the contention-based MAC layer. Based on this, MTPCR has discovered the desired routing path that has less power consumption during data transmission. And it has a path maintenance mechanism to maintain good path bandwidth. Path maintenance is activated based on the density of nodes in a network in order to reduce the overhead. The computation of power is based on the success ratio and number of nodes contending for the channel in the MAC layer.

From the above works, it is understood that each one of the method has its own advantages and disadvantages. DSR is a good reactive protocol under low mobility conditions. Under high mobility, performance degrades because of the stale route problem. For finding a route, the source node floods the RREQ to all the neighbours. Therefore overhead is more. In PAMP, path discovery process is done based on the remaining power of nodes recorded in the RREQ packet. The remaining power of all paths are evaluated to construct multiple paths to complete the data transfer. Since PAMP allows a node to process multiple RREQs for a session, it incurs more overhead in the network. In SSBR, when a node receives the RREQ, the values of RSS and broadcast time are recorded and the values are sent to the source node as RREP packet for path selection. The RSS variations are used to predict the possible amount of data that can be transmitted via a link. In MTPCR, the path selection is minimum energy but for computing the power consumption, it takes in to account the success ratio and number of nodes contending for the channel. However, in all these, they have not concentrated on reducing the flooding in path discovery based on RSS and residual energy. These factors bring down some of the following problems; insufficient energy leads to node failure in the selected path, more distance between two nodes give rise to low signal strength etc., Therefore, in our proposed method (PDSEER), path discovery, and selection are focused. In path discovery, nodes that have low received signal strength and residual energy are not allowed to take part. Therefore it eliminates unnecessary flooding of RREQs and thereby it minimizes the energy consumption. Path selection in the proposed is based on selecting the path that has minimum energy consumption for data transfer.

3.0 PROPOSED ENERGY EFFICIENT ROUTING PROTOCOL

The main focus of the design is to reduce the energy consumption during data transfer with the help of path discovery and selection. The reason for adopting both path discovery and selection is due to mobile nature of the nodes. Before initiating the path discovery process, transmit power required is adjusted based on the selected number of one hop neighbours. For ensuring the stability of the route for a certain period of time, RSS value is selected. RSS in the path discovery is used to predict the connectivity failure between nodes in the links. The following sections describe the proposed PDSEER, network model, path discovery process with transmission power adjustment, energy consumption analysis and at last the path selection methodology for the proposed work.

3.1 PDSEER Framework

The proposed algorithm, PDSEER consists of two steps; one is path discovery based on RSS and residual energy and another is path selection for data transfer based on minimum energy consumption. The proposed method is based on DSR protocol. For the design, RREQ packet of DSR is modified in such a way that it contains one additional field called energy consumption. The complete steps for executing PDSEER are given below:

1. Select the source, destination, and total number of one hop neighbours.
2. Determine the maximum transmission range and power.
3. Broadcast RREQ with the adjusted power to all one hop neighbour nodes.
4. Measure the RSS value and compare it with the rest of the received values.
5. Select the nodes having high RSS value.
6. Measure the residual energy.
7. Choose the nodes for forwarding RREQ.
8. Measure the energy consumption.
9. Update EC_{ij} field in the RREQ for each and every link for computing EC_{SD}.
10. Send the RREP to the source node after selecting one minimum energy path.

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3.2 Network Model

For designing PDSEER, the network is modeled as a graph G=(V,E) containing the set of nodes and links. 'V' here is taken as total number of nodes 'TN'. The set TN contains nodes which takes part in rebroadcast (TN_R) and non-rebroadcasting nodes (TN_{NR}) denoted as $TN = (TN_R \cup TN_{NR})$. Proposed path discovery mechanism is designed in such a way that the ratio of reliable nodes (TN_R) to total number of one hop neighbour nodes (N) is always greater than zero. So, at least one path will exist. It is evident that from Eq. (2), that the existence of a link depends on the number of neighbours. The probability of path discovery can be found out if ($N>TN_R$) using the formula.

$$ P_{PD} = \frac{(N - TN_R)}{N} \tag{2} $$

where N - Total number of one hop neighbours;
TN_R - Number of neighbours forwarded the RREQ;
TN - Total nodes in the network;

For an example, if a network contains a node with five neighbours, with atleast one reliable node, based on Eq. (2), P_{PD} is 0.8. This ensures definitely there is a path for the destination.

3.3 Path Discovery Process

To discover a route reactively, the source node after choosing the number of neighbours, broadcasts a single RREQ message, which is received by almost all nodes currently within the transmission range of the source node. Then the transmit power level is adjusted inorder to avoid the power wasted for transmitting the data to the nearest neighbour nodes. This power reduction leads to energy saving. So, this adjustment is done based on the parameter called Transmission Range maximum (TR_{max}). TR_{max} is defined here as the maximum distance between any two nodes. This value is calculated based on the following equation.

$$ TR_{max} = \frac{R}{10 \times TN} \sqrt{\frac{\log N}{N^2}} \tag{3} $$

Eq. (3) will hold good and give optimum results only if the following conditions are satisfied.

$$ TN \geq (R)^{1/3} \; ; $$
$$ TR \geq \frac{\sqrt{R}}{4} \quad \text{and} $$
$$ N \geq 3 \; ; $$

Where R - Area of the network;
TR - Defined Transmission Range;

The transmit power (P_t) required for the transmission is updated as follows,

$$ P_{t\_adj} = f(N, TR_{max}, TR, P_t) \tag{4} $$

$$ P_{t\_adj} = \frac{N + TR_{max} \times P_t}{TR} \tag{5} $$

Transmit power adjustement (P_{t_adj}) is done mainly to reduce the energy consumption based on transmisson range of one hop neighbours as per the Eq. (5). Path discovery after adjusting the power level is done based on a bi-objective function namely RSS and remaining energy of the node. By using RSS value, the nearest node can be selected for forwarding the data. Second remaining energy is checked for determining the node lifetime. The

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main aim is that in route discovery phase, a mobile node has to choose a neighbour with highest RSS value which means the node is at minimum distance as per Eq. (7) to improve the lifetime of the path. Based on Friis transmission formula [31], the *RSS* in dBm for free space propagation of the links is computed using the Eq. (6) as,

$$RSS = \frac{P_t G_t G_r}{L} \left(\frac{\lambda}{4\pi d} \right)^n \qquad (6)$$

Where λ is wavelength in meters, P_t is transmitting signal strength in dBm, G_t and G_r denotes the unity gain of the transmitting and receiving antennas. d is the distance between transmitter and receiver in meters. n is path loss coefficient and takes a value of 2 to 4 and L is path loss component ($L=1$). Usually value '2' is for free space model and '4' for two ray ground propagation model. The noise and fading are not considered for the design. The above Eq. (6) is rewritten as follows,

$$RSS = \frac{P_t}{d^2} \qquad (7)$$

From the Eq. (7), it can be seen that if *RSS* value is more, link quality will be good, otherwise link is likely to be broken soon. The RREQ of DSR is modified by appending the fields such as Received Signal Strength (RSS) and Energy Consumption for the Source to Destination pair (EC$_{SD}$). Each replica of the RREQ checks the RSS of the links that it traverses for the reliable path formation. Initially, source node will carry the transmit power level as the RSS and it is broadcasted to the neighbour node. The neighbour node maintains a table containing the RSS values received from other nodes. The neighbour will update the RSS based on the following. When a node which is not the destination receives the RREQ, it checks whether the current received signal strength of RREQ is greater than or equal to the previously stored RSS values of other nodes RREQ in the routing table. The current node after predicting its closeness makes a final decision based on its residual energy of the node for forwarding / rebroadcast RREQ. Otherwise, the current node drops the forwarding job.
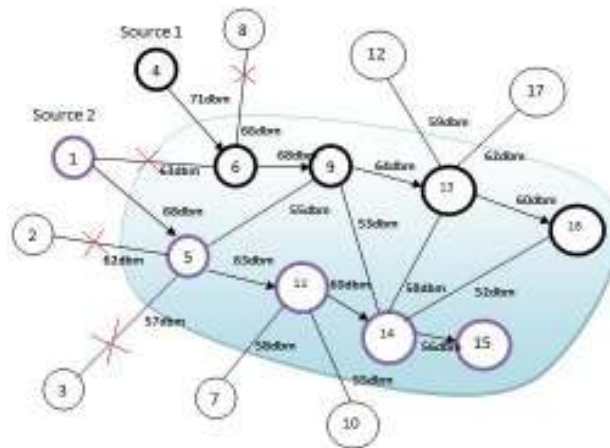

Fig. 1. An example showing RSS based RREQ Forwarding by a Node

A diagrammatic representation of forwarding node selection scenario based on RSS is shown above in Fig. 1 with an example. Fig. 1 is a sample network consisting of 17 nodes in which two nodes namely node number 4 and 1 are the source nodes and node number 16 and 15 are the destination nodes. These two source nodes are forwarding the RREQ. The RSS validation for the source node number 1 is explained here as follows. Source 1 (here node number 4) starts discovering the route by initiating RREQ to 6. Node number 6 checks whether it is eligible for forwarding the RREQ. Node 6's received RSS value of RREQ is 71dBm and it is checked with the already stored RSS values received from 8 and 1. It is found that the present RSS value is higher and it is assumed that node 6 is closer to the source than to the other nodes. Then its residual energy is validated based on the Eq. (8). The decision is taken that node 6 is eligible for forwarding. The same steps are followed by each and every node, once it receives the RREQ. Normally, as the distance increases, the received signal strength starts decreasing. This increases the chances of link breakage between two nodes. So, to minimize this, path discovery process is done based on RSS and the steps in the procedure is given as an algorithm below.

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When a node receives a RREQ, it compares current RSS_{rec} with the RSS already recorded in the routing table and proceed as given in algorithm 1. In this CN represents Current Node and DN represents Destination Node.

Algorithm. 1 RSS Based RREQ Forwarding

```
If RSS_rec ≥ RSS then
{
    {
    If (CN ≠ DN) then
    Rebroadcast RREQ
    else
    Send RREP
    No rebroadcast of RREQ
    }
else
drop the RREQ
}
```

After comparing RSS of the neighbours RREQ, the current node decides whether it is eligible. If the residual energy of the nodes has not been taken into account, there are chances that the discovered paths may have link nodes with insufficient energy to relay data. Initially the residual energy value is kept as initial energy. Residual Energy threshold ($ResE_{i\_thres}$) is calculated based on Eq. (8). Then residual energy of the node 'i' is validated based on Eq. (9) for the relay nodes for finding whether they can participate or not in the data transmission by forwarding the RREQ to the neighbour.

$$\mathrm{Re}\,sE_{i\_thres} = \mathrm{Re}\,sE_i \times \frac{No.ofRREQ\_forwarded}{No.ofRREQ\_received} \tag{8}$$

$$\mathrm{Re}\,sE_{i\_thres} \geq \frac{IE_i}{5} \tag{9}$$

$ResE_i$ represents residual energy of the node 'i'. IE_i is nothing but the initial energy of the node 'i'. By reducing the number of RREQ and by utilizing variable transmit power in the path discovery process, energy conservation can be obtained. The nodes which are far away from the sender and also having very less energy are eliminated from participating in data transfer. This results in the reduction of number of RREQs flooding the network. This kind of filtering at each node helps in reducing the routing overhead. If the current node is the destination, it also does the same, but it does not rebroadcast the RREQ. Instead it sends a unicast RREP to the source node. The computation times at node places will depend on the network size and traffic conditions, and usually is a design choice.

3.4 Energy Consumption Analysis

The proposed PDSEER computes the energy consumption for one transmission as follows and it is updated in the EC_{SD} field of RREQ. Eq. (10) denotes the energy consumption from the source node to the destination (SD pair) for all the (M-1) links. M represents the number of nodes in the path. Energy consumption of the individual link EC_m between a pair of nodes i and j is given in Eq. (11) as EC_{ij}.

$$EC_{SD} = \sum_{m=1}^{M-1} EC_m \tag{10}$$

$$EC_{ij} = EC_{txi} + EC_{rxj} + EC_{sleepj} + EC_{transj} \tag{11}$$

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The energy consumption for transmission from node 'i' is calculated based on the following Eq. (12) and the other terms are also computed similar to this. In this EC_{txi} is energy consumed / spent for the transmission of data by node i; P_{txi} is power consumed for the transmission; T_{txi} is time spent for the transmission; EC_{rxj} represents energy spent for receiving data by the node j; EC_{sleepj} is energy spent in the sleep state j and EC_{transj} is energy spent for the transition from awake to sleep for node j.

$$EC_{txi} = P_{txi}T_{txi} \tag{12}$$

The proposed work utilizes the power saving mode of IEEE 802.11, the source node buffers packets for the destination node that is in the doze/sleep state, and these buffered packets are announced during a subsequent ATIM window. In this, a duty cycle contains an active period and a sleep period, where a node can communicate with another node only in the active period. When a node has sent an ATIM frame to another node, it remains awake for the entire beacon interval. The node that receives an ATIM frame replies by sending an ATIM-ACK. A node that has no packets to be transmitted can go into the doze state at the end of the ATIM window if it does not receive an ATIM frame. All dozing nodes again wake up in PSM at the start of the next beacon interval. Nodes in the PS mode are expected to synchronize among themselves in a distributed way [14]. A power management mode is mainly chosen to reduce the energy costs of the idle state, but it exhibits poor latency performance in multi-hop infrastructureless environments. For the simulation, Monarch version [8] is used for the 802.11 power management in ad-hoc networks. It is also assumed that nodes utilize the power consumption model utilized in [13]. The values are 1.4, 1.0, 0.83, and 0.013 watts in transmitting, idle receiving, idle listening and low power sleep states respectively.

3.5 Path Selection Process

After discovering the reliable paths for the data transfer, path selection is done based on the minimum energy consumed paths to reduce path breakage and to increase the data delivery rate. The energy consumption is calculated based on the Eq. (10) and (11) and it is updated in the RREQ field. Once all the RREQs are received by the destination, it will select the path that has minimum energy consumption based on the Eq. (13).

$$MECP = \min\left(EC_{SD}\right) \tag{13}$$

MECP represents Minimum Energy Consumption Path. Based on this, we can find the desired path that will consume the least amount of energy. The destination will give a RREP based on the above criteria to the source node. Then the source node will make a data transfer using this minimum energy path. Thus with this path selection process, the transmission of data can be made efficiently.

4.0   SIMULATION RESULTS AND ANALYSIS

The performance analysis of the design is done using the network simulator [29]. The simulation analysis involves the path discovery mechanism and path selection algorithm. The simulation setup parameters for the design are given in Table 1. The initial transmit power level is chosen as 200mW (23dBm) which is a typical value of wireless local area network devices operating at 915MHz. The parameters for the analysis are control packets and energy consumption in the path discovery process and packet delivery ratio, energy consumption and number of path breakages in path selection process. Mobility model is Random Way Point (RWP) model [2]. Simulation time is 900 seconds and the results are taken after 10 runs to obtain steady state value. The proposed PDSEER is compared with DSR, PAMP, SSBRn and MTPCR.

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Table 1. Simulation Setup Parameters

Parameter	Value
Network Topology Size	1000×1000 m^2
Number of Nodes	100-150
MAC Type	IEEE 802.11 DCF
Radio Propagation Model	Free Space
Transmission Range	250m
Data Rate	2 Mbps
Maximum Node Speed	5 m/s
Packet Injection Rate	1-5 packets / sec
Initial Energy	180 J
Traffic Type	CBR
Data Size	5 Mbytes
Packet Size	256 bytes
Pause Time	0-600s
Simulation Time	900s
Mobility model	Random Way Point

4.1 Overhead Analysis

The analysis for the number of control packets used for finding a path based on RSS for different number of nodes is plotted in Fig. 2. It can be seen from the above analysis that the number of control packets for the proposed method is lesser compared to SSBR and MTPCR because of the restricted number of RREQ broadcasting based on RSS and residual energy. The reason for higher number of control packets in the proposed compared to DSR and PAMP are due to the reliable path discovery. So, the number of RREQs broadcasted for setting up the path becomes more. The number of control packets in DSR is approximately 60% higher than that of PAMP which is based on AODV. In PAMP, path is selected based on the amount of data and power available. After receiving all RREQs, the destination node records and decides by giving RREPs for all collected paths to the source node in order to construct multiple paths. So, overhead is lesser for PAMP than all the other schemes.
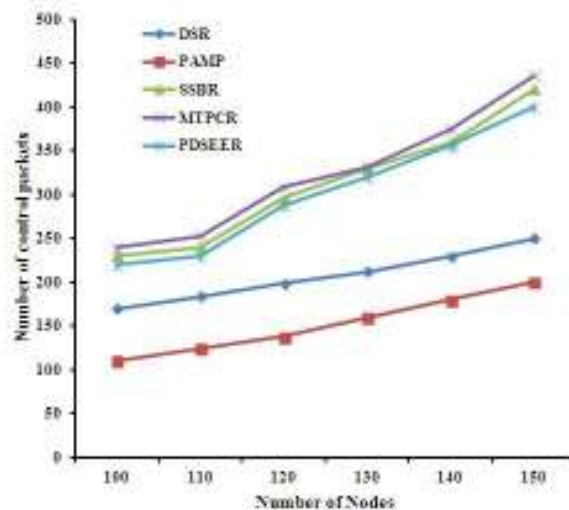

Fig. 2. Number of Nodes vs. Control Packets

In SSBR, path selection is done after predicting the amount of data transmitted and the remaining power of nodes. So, source gathers all the RREP for the selection. Hence the overhead of SSBR is higher. In MTPCR, path is selected as least power consumption path by taking into account the success ratio and MAC contentions. Proposed achieves 8.5% and 4.5% lesser overhead compared to MTPCR and SSBR respectively.

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4.2 Energy Consumption Analysis

Energy consumption analysis in the path discovery process is shown in Fig. 3 and it is purely dependent on the number of control packets and the maximum transmission range value i.e. number of one hop neighbours.
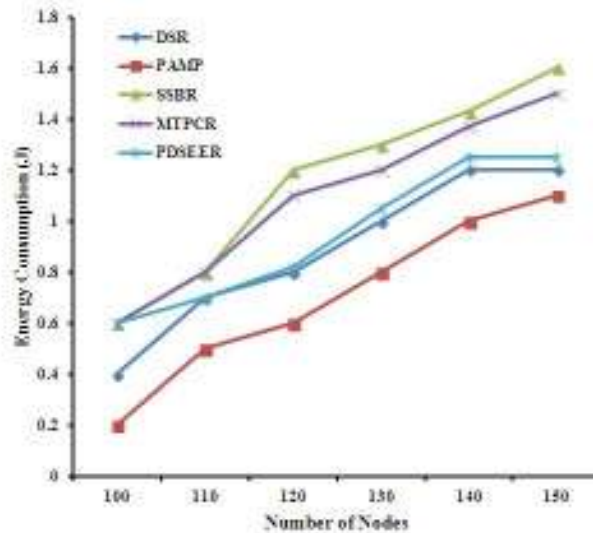

Fig. 3. Number of Nodes vs. Energy Consumption (J) in path discovery process

The results in Fig. 2 and 3 show a similar pattern. It is evident from the above Fig. 3, path discovery ends up in lesser energy consumption in the proposed PDSEER compared to SSBR and MTPCR. When the number of nodes are 100, the energy consumption is same. But as the nodes are increasing, proposed achieves an average of 10% and 14% lesser energy consumption than MTPCR and SSBR. The reason behind this is that PDSEER utilizes transmit power control as well as power saving mode for its MAC operation. PDSEER energy consumption is higher compared to DSR and PAMP is that it initiates large number of control packets for the path discovery. But the overall energy consumption of PDSEER is lesser compared to all the methods.

4.3 Packet Delivery Ratio

Packet Delivery Ratio (PDR) is shown in Fig.4 by varying the packet injected rate in network from 1 to 5 packets / second and keeping the total number of nodes as 100.

PDR is higher in proposed system. This is due to the reason that the PDSEER finds reliable paths for data transfer by choosing the nodes whichever is nearer based on RSS and having more residual energy and also it selects path that consumes minimum energy. The path breakage due to node failure are lesser. And also it avoids unnecessary retransmission. Thus it reduces energy consumption during data transfer and PDR increases. When the packet injection rates are low, PDR of PDSEER is above 90%. SSBR finds the possible amount of data that can be transmitted before transmission by considering the RSS variation and the bandwidth. Hence, PDR is lower compared to PDSEER and MTPCR. When PDSEER is compared with MTPCR, PDR of the proposed is same as that of MTPCR, when the packet injection rates are 2 and 5. When compared to PAMP, PDR is lesser, because PAMP is mainly designed for static networks, so if there is mobility, then the multi paths selected may contain a node which is far away from the sender and there are lots of chances for a packet loss.
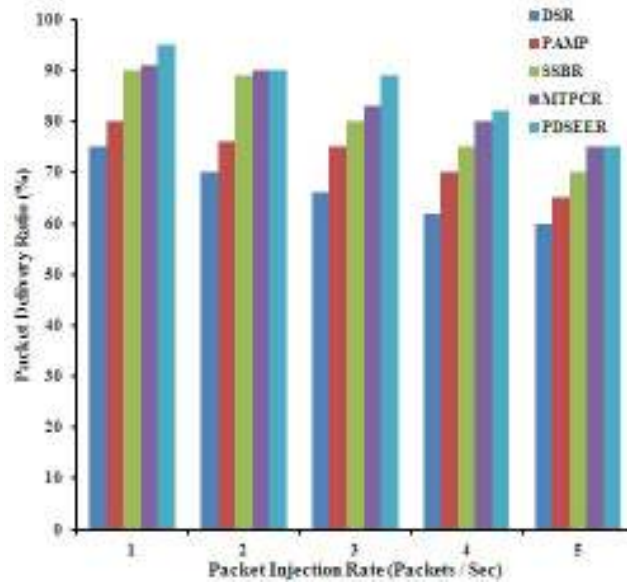
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Fig. 4. Packet Delivery Ratio

4.4 Number of Path Breakages

The number of path breakages is plotted in Fig. 5. It can be seen that PDSEER has an average of 32 path breakages for the varying network sizes of 100 to 150 nodes. But MTPCR is achieving lesser number of path breakages than the proposed, because it involves path maintenance mechanism. When the proposed is compared with other methods like DSR, PAMP and SSBR, path breakages of PDSEER are very much lesser. This is due the residual energy consideration in path discovery. In DSR, the number of path breakages is more out of all the methods. Because, it selects the path with minimum number of hops. The chances for path breakages are more, because of the dynamic network topology. In PAMP, the path selection is multiple in numbers and depends on the data and power available. It does not concentrate, whether the nodes are nearer or far for the transmission. Hence, chances for path breakages are more.
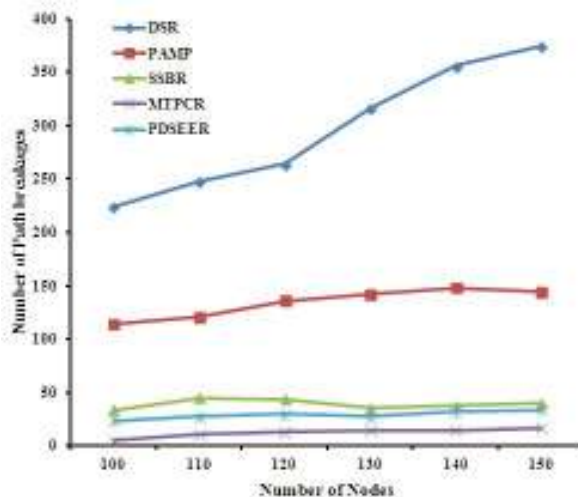

Fig. 5. Number of path breakages

SSBR selects the path based on the transmission range of the receiver and also the remaining power for data transmission. Therefore, rerouting paths are reduced in SSBR. And also there are lesser number of node failures.

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4.5 Energy Consumption for PDS

Energy consumption for path discovery and selection is represented in the following Fig. 6. The energy consumed is plotted for one byte of information. It is seen that the proposed achieves a very less energy consumption compared to all the other methods. This graphical result is also based on the assumption that the number of neighbours as 5 and pause time as 300s.
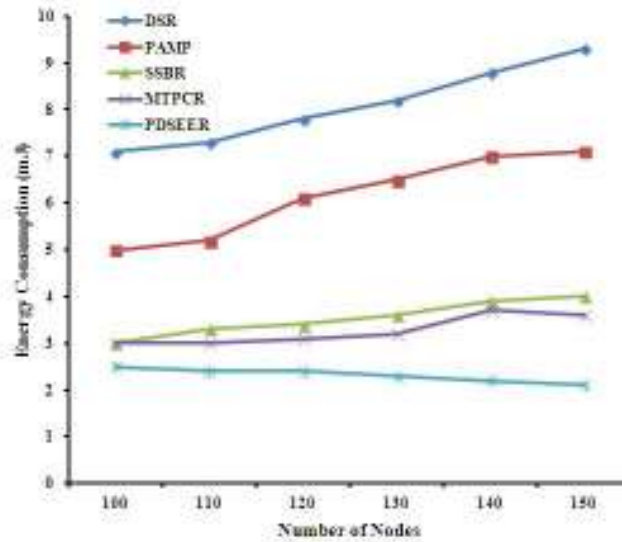

Fig. 6. Energy Consumption vs. Number of Nodes

The reason behind the reduction is that the proposed design utilizes the transmit power control and also iminimum energy paths for the data transfer. Therefore, in the proposed unnecessary route discovery is reduced. This is because the proposed design keeps the nodes which does not take part in transfer to be in sleep mode.

4.6 Analysis of Theoretical and Simulation Results

Transmission range maximum (TR_{max}) and tranmission power control adjustment (P_{t_adj}) is given in table 2. by keeping the number of neighbours N=5 and by varying total number of nodes from 100 to 150.

Table 2. Comparative Analysis of Theoretical and Simulation Results

TN	TR_{max}		$P_{t\ adj}$	
	Theoretical	Obtained	Theoretical	Obtained
100	167	175	134	140
110	152	160	122	128
120	139	145	112	116
130	129	131	103	104
140	119	124	95	99
150	111	120	89	96

From the above table, it is understood that there is a small difference in transmission range calculation and power required for transmission based on theoretical and simulation results. The theoretical transmission range maximum (TR_{max}) is obtained by assuming the number of one hop neighbours 'N' as 5 and network area 'R' as 1000 m x 1000 m. Power required for transmission (P_{t_adj}) is calculated based on the theoretical TR_{max} , by setting the transmit power level 'P_t' as 200mW and transmission range 'TR' as 250.

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4.7 Energy Consumption Analysis of PDSEER - with and without Transmission Power Control

Energy consumption for the proposed path discovery and selection with Transmission Power Control (TPC) and without transmission power control is plotted in Fig. 7.
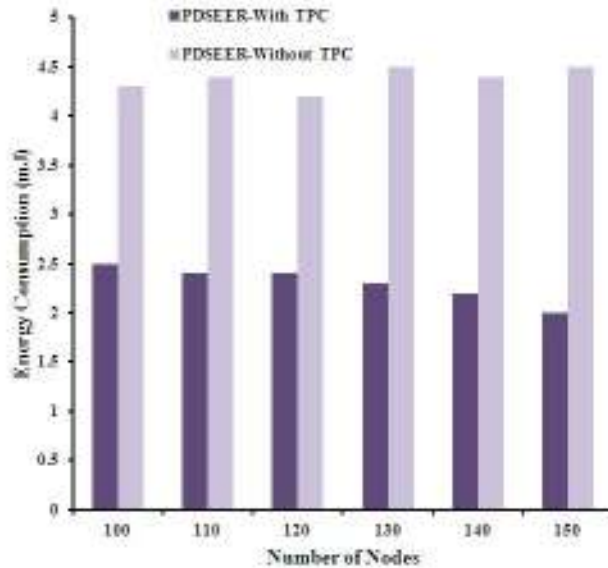

Fig.7. Energy Consumption Analysis of PDSEER for with and without TPC

It is clearly seen that power reduction based on transmisison range results in energy saving. The graph is plotted by varying the nodes from 100 – 150 and by keeping the pause time as 300s and number of neighbours as 5.

4.8 Comparative Analysis for Energy Consumption of PDSEER

Comparative analysis for the energy consumption is done based on number of neighbours and pause time. Table 3a. gives an outline of energy consumption (mJ) for different number of nodes by varying the neighbours as 5, 10, 15 and 20. It can be interpreted that the number of neighbours in a network is inversely proportional to the energy consumption. The minimization of energy consumption depends upon the neighbours and selection of the path for data transfer. If the neighbours are more in number, then the distance between the nodes is going to be minimum, the power required to transmit is reduced resulting in energy saving.

Table 3a. Comparative Analysis for Energy Consumption

Total nodes	Energy Consumption (mJ) for different Number of Neighbours			
	5	**10**	**15**	**20**
100	2.5	2.4	2.1	1.8
110	2.4	2.2	2.1	1.8
120	2.4	2.1	2	1.6
130	2.3	2.1	1.9	1.5
140	2.2	2.1	1.8	1.3
150	2	2	1.6	1.2

Table 3b. represents the energy consumption analysis by varying the pause time from 0 sec. to 600 sec. This is

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shown diagrammatically in the following Fig. 8. It can be seen that below the pause time of 300 seconds, the energy consumption is getting increased. This is due to the reason that due to high mobility, the path in the cache may not be useful and it results in discovering new routes.

Table 3b. Comparative Analysis for Energy Consumption

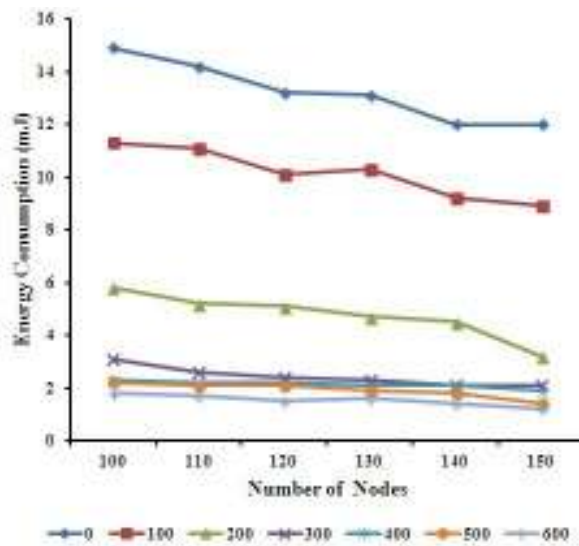| Total nodes	Energy Consumption (mJ) for different Pause Time (sec.)						
	0	100	200	300	400	500	600
100	14.9	11.3	5.8	3.1	2.3	2.2	1.8
110	14.2	11.1	5.2	2.6	2.2	2.1	1.7
120	13.2	10.1	5.1	2.4	2.2	2.1	1.5
130	13.1	10.3	4.7	2.3	2.1	1.9	1.6
140	12	9.2	4.5	2.1	2.1	1.8	1.4
150	12	8.9	3.2	2.1	1.9	1.4	1.2

Fig. 8. Energy Consumption Analysis for different values of Pause Time

It can be concluded that the proposed system achieves good energy consumption for the pause time from 300 seconds to 600 seconds. Hence, it can be said that from the simulation results that the proposed PDSEER is best suited for the medium mobility condition.

5.0 CONCLUSION

The proposed PDSEER is used to select the minimum energy consumption path for data transfer after discovering the path based on RSS and residual energy and adjusting the transmit power based on transmission range. Reliable path selection based on RSS and residual energy is mainly to reduce the path breakages due to node failure. Selection of the path that consumes less energy will definitely extend the network lifetime. So, the design is proposed keeping in mind to reduce the energy consumption and path breakages. From the simulation results, it is noted that the control packets and energy consumption for the path discovery process is appreciably increased compared to DSR, PAMP and it is decreased compared to SSBR and MTPCR. Reason for this is due to the finding of reliable paths for data transfer. The other factors like PDR and overall energy consumption for transferring single byte of information are very much lesser. Only the number of path breakages are found to be higher than the existing MTPCR. From the simulation analysis, it is understood that the proposed PDSEER consumes much lower energy compared to DSR, PAMP, SSBR and MTPCR. The system gives an optimum

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performance for the pause time varying from 300 sec. to 600 sec.

The system can be enhanced in many ways for extending the lifetime of the network. Further, this can be extended in many ways for network lifetime improvement by reducing the sharing of nodes in path selection with the help of node disjoint paths or for higher energy consumption with transmission bandwidth considering the number of hops into account.

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