Multistage Energy Efficient Cooperative Routing Technique for Wireless Ad-Hoc Networks

Srinivasa H P, Kamalesh V N

***Abstract:** In the recent years cooperative communication and routing has drawn the attention of the researchers primarily on the energy efficacy aspect in a general wireless networks. The lifetime of the network and energy utilization need to be improved in wireless communication network. The cooperative model has proved to be one of the best techniques for enhancement of network lifetime and also energy balancing among the nodes in wireless networks. In this research article proposes a novel multistage energy efficient cooperative routing technique which enhances the lifetime and energy efficiency. The multistage cooperative model is designed to find the set of neighboring nodes which cooperatively participate for transmission. Later the cost of link matrix is calculated for those set of cooperative nodes. The multistage cooperative routing mechanism is proposed based on multistage cooperative model and optimal link cost to minimize the routing cost. The simulation results of the proposed scheme shows that, it has enhanced energy efficiency and the lifetime of network for various number of performance metrics. The results obtained may be compared with the existing techniques.*

***Keywords:** Multi-stage cooperative transmission; cooperative routing; energy efficiency; network lifetime*

I. INTRODUCTION

Recently demand for high-speed wireless networks has increased and has moved the development of wireless ad-hoc networks. The wireless ad-hoc networks are equipped with single transceiver antenna for exchanging data between nodes. If direct communication is not possible then the network uses neighbor nodes for exchanging data. The energy of the communicating nodes is a critical constraint. This constraint reduces the lifetime of the network structure. In this perspective, the distinct characteristics of wireless networks lead to more refined design of protocols and algorithms. In order to overcome the above problems, the cooperative routing was found useful [1–2] in wireless networks. The research has found that there is improved energy efficiency by using more number of single antennas for cooperating and routing the packets between end to end transmission nodes. The packets will be transmitted cooperatively between the nodes. Furthermore, by combining the routing techniques and physical layer with reference to cooperative communication a cross layer routing schemes may be developed [3]. Based on the cross layer technique the power related to cooperative node may be allocated in that route.

To maximize the end-to-end transmission performance, many authors have proposed several schemes. The minimizing total energy routing (MTE) has used less energy, the minimum energy non-cooperative path (CAN) uses less energy during routing in non-cooperative setup [4-5]. The progressive cooperative routing (PC) uses cooperative progressively as and when required [5]. The cooperative cluster-based routing (CwR) and cooperative shortest path algorithm (CSP) creates cluster and finds shortest path among clusters [6-7]. The relay selection-based cooperative routing (CC-OPT), power efficient location-based cooperative routing (PELCR) uses relay node for achieving energy efficient and minimum-energy cooperative routing (MECR) has high degree of energy efficiency [8-10].

The literature survey carried out by [11-15] has been published and shows there is an increased network lifetime. The complete lifetime of network reflects the energy balance in the network. The links residual energy is used by flow augmentation (FA) scheme to avoid less energy node to be active node in data transfer [12]. Due to this the lifetime of the network will not be increased. The flow augmentation cooperative routing (FACR) added one to one cooperative communication method and it uses residual energy as cooperative link cost and chooses neighbours node as cooperative node by the transmitters [13]. The energy-balanced cooperative routing (EBCR) has calculated the lifetime of network from its previous single hop transmissions and it picks the set of nodes which has higher lifetime energy to choose has primary node in the network [14]. Further it also stabilizes the energy of the network. The network should have more disjoint paths for more survivability and fault tolerant [15-17].

Based on the study of research of the above papers, we are proposing a multistage energy-efficient cooperative routing (MEECR) scheme for achieving energy efficiency and to enhance the lifetime of network.

Our study concentrates on Multistage Cooperative (MSC) transmission model where the primary node is introduced to determine the Primary set for cooperation in distinction with the existing systems.

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The proposed MEECR scheme can meet various performance requirements by reducing the cost of end to end nodes transmission. The scheme will also adapt to the vanishing environment. The simulation results will show the benefits of proposed MEECR protocol will examine the network parameters like residual energy, lifetime of network, and average end-to-end transmission delay and energy efficiency in comparison with the existing schemes.

II. System Model and Existing Schemes

The system model consists of n nodes in wireless network with single antenna distributed over an MxM network randomly. The multi-hop network will be created by self-organizing among these nodes. The complete network can be mathematically modeled by means of connected undirected network graph structure n= (V, E), where V is a non empty set whose elements are communicating nodes with |V|= n. Further the elements of E represent communication links which are bi-directional between pairs of nodes. There is only one active communication session from V_s to V_d at any instance of time.

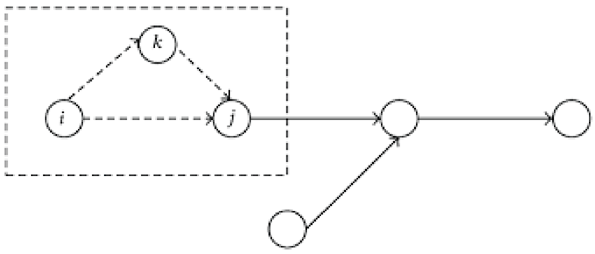

Fig 1: Cooperative Model

The existing schemes for routing is based on link cost MTE [4], PC-l [5] mainly focus on minimizing the delay of end-to-end transmission energy consumption, and FA [12], FACR [13] which are designed to maximize the life time of a network.

- **MTE transmission scheme** uses the minimum transmission cost C_{ij} between node i and j for packet delivery [4].
- **PC-l transmission scheme** presents a new cooperative model called multipoint to point cooperative model with minimum transmission power link cost to form a cooperative link among nodes.
- **FA transmission scheme** improves the lifetime of a network with the help of normalized residual energy for its transmission in the network [12].
- **FACR transmission scheme** enriches FA to enhance the network lifetime with cooperative transmission [13].

III. Proposed Multi-Stage Cooperative Routing Technique

The proposed multistage energy efficient cooperative routing needs to design a MSC transmission model for the calculation of link cost which will be considered as one of the essential factor for the selection of route. Then, the MEECR algorithm selects the optimised link cost in the multistage network with optimal shortest path for cooperative routing. It is noted that the proposed MEECR is also designed based in contrast with existing methods for better cooperative transmission model. The proposed model is reengineered and added with residual energy and the link cost to achieve a better cooperative routing.

3.1. Multistage Cooperative Transmission Model

The following are the basic definitions of some of the elements used in the proposed multistage energy efficient cooperative routing model.

Primary candidate node: If a node m has a better route with very good channel condition to node i than the receiver node j, the node m is called as Primary candidate node. The $N_{i,j}=E_{i,m}>E_{i,j}$ where m is in N (set of nodes).

Primary node: If a node is selected as primary node and has same power in the channel link between i and j then the data transfer will happen directly between i and j has primary node.

Primary set: The Primary set S(u) is frames by considering a set of nodes which are reachable between i and j with better channel link power than the primary helper. If u=i then S(u)={i};

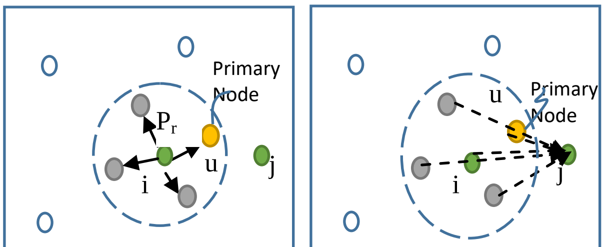

Fig 2: Multistage Cooperative Transmission Model

In the proposed scheme, i want to transmit data D to j, the data transmission will complete in two stages.

Stage 1: The node i selects primary node from a set of $n_{i,j}$. The selection of the primary node i is based on the channel power.

Stage 2: The node i transmit data to j cooperatively by selecting primary node m in S(u) and transmit data D using multistage energy efficient cooperative routing scheme.

3.2 Multistage Link Cost

The link cost between i^{th} node and j^{th} node by is calculated by considering primary node by using the relationship

$$C_{i,m,j} = C_{i,m}+C_s(u)_{,j} \quad (1)$$

where C is the link cost of a node.

The initial broadcast link cost is calculated using

$$C_{i,u} = (E_{ini}/E_i)^y.P_t, \quad (2)$$

where y is normalised residual energy effect, E is the energy and P is Packet. The packet transmission in second stage is performed by cooperative selection mechanism among the set S(u) as minimum cost calculation among a set of nodes.

$$C_{\tau(u),j}=\min((\sum_{t\in\tau(u)} (E_{ini}/E_i)^y.\gamma_i>\gamma_{min})) \quad (3)$$

Which minimises the total weighted transmission power.

By selecting the best primary node, the cooperative primary set of the link i to j can be optimized and the number of cooperative nodes can also be determined.

Algorithm: Selection of Primary node

1: Obtain the set of Primary candidate node $U_{i,j}$ for link $P_{i,j}$

2: Traverse $u\in U_{i,j}$, and calculate the related multi-stage link cost $C_{i,u,j}$

3: Determine the primary node with the optimized multi-stage link cost $C^{msc}_{i,j}$

4: The link $P_{i,j}$ owns a primary node $u^*_{i,j} \Leftarrow$ min cost among set of S(u)

3.3 Multi-Stage Cooperative Routing Algorithm

The Multistage Energy Efficient Cooperative Routing Algorithm is proposed based calculation of the link cost in multistage cooperative transmission model.

The nodes in the network will broadcast "HELLO" message periodically to know about the residual energy, channel power information and the topology details. The link cost data collected will be maintained in the vector $C_{i,j}$ for algorithm and primary node information in S(u) for selecting cooperative node for routing.

Assume that the data packet D is transmitted from V_s to V_d, and N is a set of nodes which broadcast RREQ message to find the path for routing. The above algorithm finds the shortest path among V_s and V_d based on multi stage cooperative link cost in a distributed environment as follows:

1. Each node i calculates C_i for finding primary node U_i based on link cost calculation
2. The V_s broadcast its RREQ message with its C_s to among the S(u) and the queue gets updated as $Q=Q\cup V_s$
3. The node i finds minimum of $C_{s,i}$ and broadcasts RREQ message for V_d!=i along with $C_{s,i}$
4. The C_j gets updated for each j corresponding route based on shortest path algorithm as per $C_{s,i}+C_{i,j}<C_{s,j}$ and update $C_{s,j}$ with minimum value as $C_{s,i}+C_{i,j}$ and the route as s->i->j
5. The step 3 and step 4 will be repeated for $i=V_d$. Then send unicast message RREP message to V_s along with route path cooperative shortest path for routing the data D.

The packet data D is delivered from source along the routing path R_{MSCR} as calculated using our proposed algorithm using cooperative shortest routing path.

IV. Simulation Results

The simulation results for the above proposed schemes is designed using NS2 to prove that the effectiveness of energy efficiency in cooperative routing in comparison with existing schemes.

The simulation setup has n communicating nodes and placed randomly in MxM square meters. The simulation setup parameters are shown in table 1 with randomly selected topologies. The setup will run 50 trials for 50 randomly selected topologies and the output of the same is recorded. Each simulation as E the initial energy of all nodes initialised and after the simulation completes successfully, the residual energy will be calculated. The source and destination nodes are selected randomly by the algorithm for each simulation trial. Each source nodes selects at least one packet for transmitting.

Table 1: Simulation setup variables

Variable	Value	Variable	Value
M	50	E	1000
N	50	P	400

The performance of the proposed scheme is compared with MTE, PC-3, FA, and FACR schemes as the baselines. In the simulation process the following performance metrics are evaluated namely viz. 1. Energy Efficiency, 2. Residual Energy, 3. Lifetime of Network and 4. Average Transmission Delay (end-to-end).

Generally the lifetime of network will be enumerated keeping in view of the number of sessions from the first dead node appearance.

The average network delay (end-to- end) is enumerated by considering time slots for the packet to transmit from end-to-end (source and destination). The energy efficiency of the network structure is the number of transmission packets received at the destination with the total energy cost during lifetime of network.

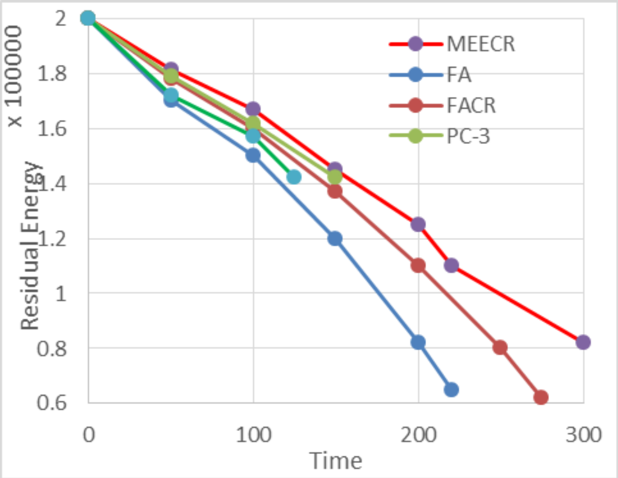

Fig 3: Time v/s Residual energy of the whole network

The simulation results in Fig 3 shows Residual Energy for a fixed number of nodes N=50 and shows MSCR has long residual energy with Y=0

The performance of network is measured by averaging 50 different network topologies each with 50 trials. It is clear from the experimental results that the energy efficiency of the network topology considered in the experiment is monotonically increasing. Further it is also observed that the network lifetime also increased with the increase of number of nodes.

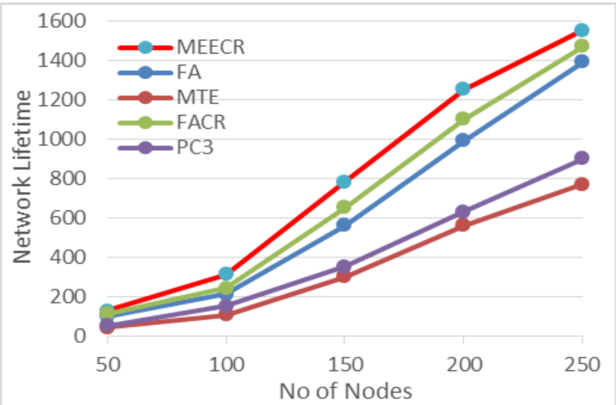

Fig 4: No of different nodes v/s Network lifetime

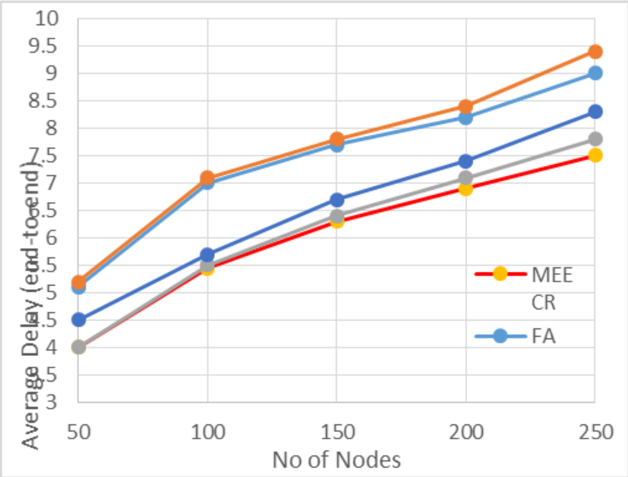

Fig 5: Nodes v/s Average Delay (end-to-end)

From the above Fig. 5, it is observed that delay (end-to-end) increases as and when the number of communicating nodes increases. Because longer the distance leads to larger signal attenuation, the power required for single transmission over longer distance is more compared to sorter distance multiple hop transmission.

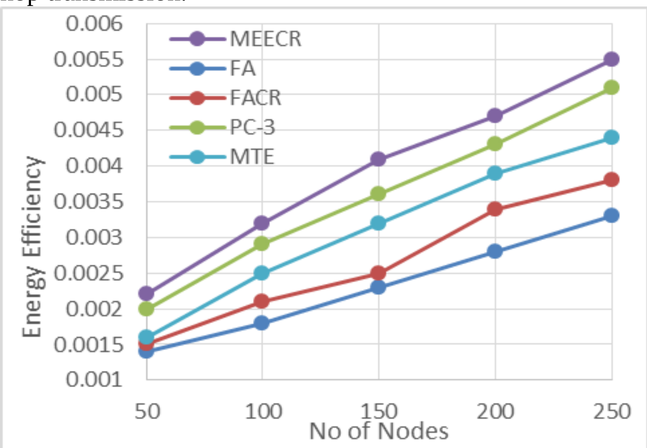

Fig 6: No of different nodes v/s Energy efficiency

The energy efficiency increases in our proposed algorithm with the increase of N as shown in figure 6. The increase of N will also increase the lifetime of network and less energy cost per end-to-end transmission. The results mentioned above shows that our proposed Multistage Energy Efficient Cooperative Routing scheme has reduced the energy cost of end-to-end transmission and enhance the energy balance of network during its transmission.

V. Conclusion

In this research article, the cooperative routing protocol for finding energy efficient path from source to destination is achieved in a multi-hop wireless network. The multistage cooperative link cost is calculated and presented. The proposed Multistage Energy Efficient Cooperative Routing technique proves that the lifetime of network has increased as well as energy efficient data transmission in a wireless environment. The simulation results clearly show that our proposed MEECR algorithm is more appropriate and efficient compared to other basic algorithms. The results obtained proved that the MEECR has increased the lifetime, reduced the delay (end-to-end) and also improved the energy efficiency. In future the proposed algorithm can be extended for multiple source and destinations and also the interference between different data flows need to be addressed.

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