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ENERGY EFFICIENT ROUTING IN MOBILE AD HOC NETWORK USING COOPERATIVE COMMUNICATION

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ABSTRACT

Cooperative communication (CC) is a competent method to acknowledge the quality of service (QoS) communication in mobile ad hoc networks (MANETs). In MANETs, mobile nodes are generally power-driven by batteries with limited energy supplies therefore, these networks are commonly known as power constrained. Topology control is to resolve the transmission power nodes so as to increase network connectivity and increase the energy efficiency. To this end, this paper utilizes the CC to link disconnected networks in order to reduce transmission power of nodes with increases network connectivity. In this paper, we propose the energy efficient routing for MANET, which exploits cooperative communication with topology control. Our approach works on physical layer with cooperative communication and proposes two routing algorithms: 1) Non Cooperative Routing scheme (NCR) and 2) Cooperative Routing (CR) scheme. In simulation results, the proposed algorithms are compared with existing methods to prove the efficiency of our proposed method.

KEYWORDS: *Mobile ad hoc network, Cooperative Communication, Energy efficient, Topology control, Routing, Transmission power.*

1. INTRODUCTION

Mobile ad hoc networks (MANET) is composed of a set of hosts, operating in a self-organized and decentralized manner, which overall forms a dynamic autonomous network and communication takes place over a wireless channel. Due to the loss in propagation path, there is a limitation in transmission radii, results in a multi-hop routing where intermediate hosts between two communicating nodes perform as routers [1]. For situations where ordinary wired networks is not achievable like battle fields, natural disasters etc, this kind of infrastructure-less network is very valuable. The nodes within the transmission range communicate each other directly otherwise communicate through intermediate nodes which are ready to forward packets. Due to this behavior these networks are also called as multi-hop networks [2]. Since nodes operating with restricted battery power, these networks are said to be power constrained. Undeniably, control of the emitted transmission power reduces the energy consumption significantly and hence increases the lifetime of the network. Though, the tuning of transmission signal strength usually entails topology alterations like loss of connectivity. Hence, transmission area has to be handled by the nodes while sustaining the connectivity of the network [3].

Routing protocols that employ different approaches have been proposed for MANET to save energy and to exploit the limited energy sources effectively and thereby extending the lifetime of the network. These approaches can be generally classified into three categories: (1) transmit power control; (2) load distribution; and (3) sleep/power down. The transmit power control approach, is employed to maintain a connected topology of the network. In the load distribution approach, the network traffic is dispersed among nodes to take advantage of the lifetime of the network. The energy consumption of nodes in the networks can also be reduced by sleep/power-down approaches and hence routing protocols that coordinate sleep/power-down approaches have been proposed to decrease the energy consumption in the network as well [4].

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Recently, cooperative communication has been taken as a promising technique and through the cooperation of users quality of service (QoS) can be improved in wireless networks [5]. Single-antenna devices are employed to work together to utilize the spatial diversity and resistance to fading, high throughput, low transmitted power, and resilient networks. A Simple cooperative wireless network is modeled with two hops there are a source, a destination, and several relay nodes. In cooperative relaying the basic idea is that the nodes which overheard the information from the source node, relay it to the destination node instead of treating it as interference. Cooperative diversity is achieved since the destination node obtains multiple independent faded copies of the transmitted information both from the source node and relay nodes [6]. Most of the existing cooperative communication works focused on physical layer issues, such as decreasing outage probability and increasing outage capacity, which are only link-wide metrics. As cooperation in essence a network solution, the traditional link abstraction used for networking design may not be valid or suitable. From the network perspectives, cooperation is not only advantageous to the physical layer, but to the whole network in several diverse aspects. There are three transmission protocols in MANETs with physical layer cooperative communications such as direct transmissions, multi-hop transmissions and cooperative transmissions.

Both direct transmissions and multi-hop transmissions can be considered as unique types of cooperative transmissions. The two types vary in a simple fact that direct transmission does not employ relays while a multi-hop transmission does not combine signals at the destination. In the meantime, the MANET topology is controllable by means of adjusting parameters such as transmission power, channel assignment, etc. In common, topology control is a design to agree on where to deploy the links and how the links function in wireless networks to structure a good network topology, which will optimize the energy consumption, the capacity of the network, or end-to-end routing performance. Topology control is initially modeled for MANETs, and wireless mesh networks to diminish energy consumption and interference. The objective of topology control is to set up interference-free connections to diminish the maximum transmission power and the number of essential channels. It is also attractive to build a reliable network topology because it will provide more benefits for the network performance. There are two features in a network topology: network nodes and the connection links. Some controllable parameters parameterize classical MANET by which they directly determine the existence of wireless links. In MANET, topology control is an important approach for conserving energy, which focuses on determining a set of wireless links among nodes so as to attain certain energy-efficient properties.

Our work proposes the energy efficient routing for MANET, which exploits cooperative communication with topology control. The traditional method proposed in [1] has improved the network capacity using topology control with cooperative communications. Anyhow energy consumption has not been considered and the network capacity has been improved significantly. This work mainly focuses on providing minimum energy consumption for MANET nodes. Our approach works on physical layer with cooperative communication and proposes two routing algorithms: 1) Non Cooperative Routing scheme (NCR) and 2) Cooperative Routing (CR) scheme. Two algorithms are compared to prove the efficiency of our proposed method. In cooperative communication, relay is crucial for packet transmission from source to destination. This paper elects the multi-hop relays as helper nodes in cooperative communication. Primarily, r-neighboring region of source node is estimated in our proposed scheme and then election of relay node is presented based on transmission power and residual energy. Once relay node is elected, cooperative communication scheme is adopted to transmit the packets. In simulation results, we compare the proposed NCR and CR scheme existing routing methods [11] [16].

Rest of this paper is organized as follows. Section 2 briefly reviews the related works on both energy-efficient routing algorithms and cooperative communications with MANETs. In Section 3, the system model and problem formulation is presented. Section 4 explains the proposed NCR and CR schemes and comparison of the proposed methods with other existing routing methods are presented in the Section 5. Next, in Section 6 we conclude the performance and efficiency of the proposed methods.

2. RELATED WORK

Cheng and Heinzelman have [7] (2008) disputed that many routes in ad hoc networks are

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short lived, triggering frequent route discovery processes, which in turn report for extra control overhead and packet latency. They suggest two schemes which allow the network to choose long lifetime routes (LLR). The optimal LLRs are computed in a centralized manner in g-LLR approach hence called, a global approach. As such information is not usually available to the nodes in a network; benchmark is mostly as its importance. In the d-LLR approach, long lifetime routes are selected in a distributed manner, using only local information. It is shown that the performance of d-LLR closely equivalent to that of g-LLR.

Mohammed Tarique and Kemal E. Tepe (2009) [4] have proposed Minimum Energy Dynamic Source Routing (MEDSR) and Hierarchical MEDSR (HMEDSR). Their performances were investigated via computer simulations. As compared to the DSR protocol, MEDSR was found to improve energy efficiency and network lifetime, mainly in dense networks. However, with increasing network size the energy efficiency drops due to routing overhead and MAC layer packets. A considerable portion of the total energy was dissipated by the overhead packets in these networks. In order to limit this overhead and improve MEDSR, HMEDSR was proposed. The HMEDSR protocol has successfully eliminated the unnecessary overhead packets, and improves considerably the performance of MEDSR. Both the HMEDSR and MEDSR provided an enormous perfection over the DSR for energy efficient procedure in MANET. As overhead of the MEDSR protocol has been auxiliary reduced by using the HMEDSR, even more energy saving could be realized by using the HMEDSR protocol instead of DSR in MANET.

ZhihaoGuo et.al [8] (2011) proposed an energy-efficient preserving algorithm which can be incorporated with proactive routing protocol in MANET. Their energy-aware routing has measured and predicted the per-interval energy consumptions using ARIMA time series model. This formulation preserved preference of residual energy and powerfully reduced unbalanced routing caused by differences in initial energy. Nevertheless, considered energy cost only not improve packet delivery ratio, and other parameters should be considered when node speed gets higher. Additionally they formulated an energy-related characteristic of power-wise heterogeneous scenarios.

Andy An-Kai Jeng and Rong-Hong Jan [9] (2011) have proposed an energy-efficient maintenance protocol to reduce the beacon power and proven that any reconstruction and power change can coverage in four and five beacon intervals. They also presented an adaptive configuration rule to configure the parameter for every node based on the node's mobility and energy levels. Finally, the proposed protocol has been efficiently reduced the overall energy consumption and network life time. In [10], SeokHoon Kang, Gwanggil Jeon and Young-Sup Lee (2012) proposed a routing protocol, which has considered the position and energy of mobile nodes. The proposed routing protocol adapted the continuous mobility by reflecting the position and energy of nodes. Thus, it has been proven that the safety of the routes and life time of the nodes was increased by constructing the balanced energy consumption considering residual energy of nodes. It showed the improvement compared to the precious protocols by improving the holding time of the route by more than 2.5 times compared to the existing protocols, and reducing the numbers of nodes that spent all the energy by maximum of 54%.

On the other hand, Ying Zhu et.al [12] have formulated new topology control problem: energy-efficient topology control problem with cooperative communication. They proved that this problem was NP-complete and introduced two new topology control algorithms using cooperative communications. Both algorithms can build a cooperative energy spanner in which the energy efficiency of individual paths was guaranteed. In 2012, Jieun Yu et.al [11] (2010) have proposed the basic centralized topology control scheme using cooperative communication (CC).The proposed scheme was presented with two helper-node selection schemes: the optimal method and the greedy heuristic method. Initially, the mobile nodes were grouped into clusters due to transmission range. They also applied MST (or DTCC) to each cluster for direct links and it achieved further power reduction. As CC has been presented, the path loss exponent and SNR were taken into the account. The proposed topology control schemes (Coop. Bridges and Coop. Bridges + DTCC) have higher network connectivity performance than the other topology control schemes.

Zehua Wang et.al [13] (2012) have proposed an opportunistic routing scheme for MANET, which was collected of three components

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are 1) PSR-a proactive source routing protocol, 2) large-scale live update of forwarder list, and 3) small-scale retransmission of missing packets. All of these have clearly utilized the broadcasting nature of wireless channels; furthermore, they achieved via efficient cooperation among participating nodes in the network. Principally, the proposed routing scheme can take different paths to the destination when packets among the same flow are forwarded. Nevertheless, the prospective of cooperative communication in multi-hop wireless networks is to be unchecked at higher layers.

Quansheng Guan et.al [14] (2012) have introduces physical layer cooperative communications comprised with topology control to improve the network capacity of MANETs. They have proposed a Capacity-Optimized COoperative (COCO) topology control method, which considered both upper layer network capacity and physical layer relay selection in CC. They have adopted the two-hop relays and divided the long link into many hops. Simulation results have shown that physical layer cooperative communications techniques have been noteworthy impacts on the performance of topology control and network capacity. Their proposed COCO method was significantly improved the network capacity in MANETs with cooperative communications.

F Richard Yu et.al [15] (2013) have presented the cooperative communications with MANETs to design security and QoS co-design of MANET also proposed a game theoretical approach. The proposed method has enabled the source to advantageously select its relay by energetically updating its belief in the maliciousness of relays according to its record of attacks with the consideration of system throughput and system security requirement. This method is limited to utilize the relays i.e. it can choose only two-hops as relays. In [16], Angelos Antonopoulos (2013) have presented a network coding-aided energy efficient protocol for MAC layer, which has coordinated the transmissions among a set of relay nodes which act as helpers in cooperative Automatic Repeat re Quest-based (ARQ-based) wireless networks. The proposed solution has significantly improved the energy efficiency up to 80% without compromising the offered QoS in terms of throughput and delay.

3. SYSTEM MODEL

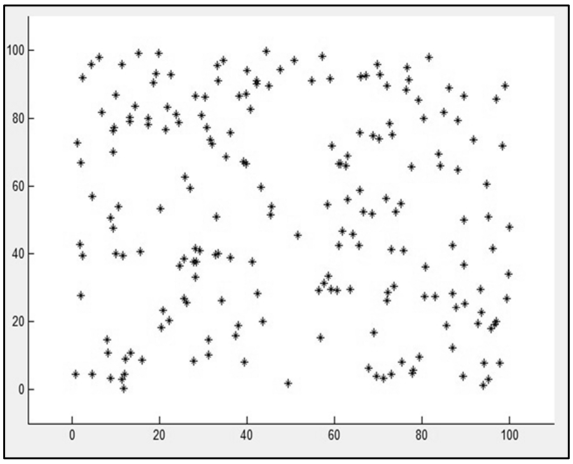

Fig.1. System model of the simulated Manet

We consider a MANET with N nodes which are assumed with the capacity of receiving and decoding the received packets in due to the concept of cooperative communication. Our system model presented in fig.1 is similar to those of [11] [12].Every node n∈N has a maximum transmission power limitP_{MAX} andP_i is the available transmission power of node i.$\alpha$is the path loss exponent and τ is the minimum average SNR to decode the received packet.$D_{i,j}$is theEuclidean distance between node i and node j. For a sourcenode i to communicate with node j directly, theymust satisfy the eq. 1

$$P_i(D_{i,j})^{-\alpha} \leq \tau(P_i \leq P_{MAX} \quad (1)$$

If nodes in β transmit concurrently, i.e., apply cooperative communication technique, the following eq.2 must be satisfied for correct decoding at destination node j.

$$\sum_{i\in\beta}^{n} P_i(D_{i,j})^{-\alpha} \leq \tau\ (P_i \leq P_{MAX}) \quad (2)$$

The simulated network is modeled as a 2-dimensional directed graph: $G = (V,)$, where$V = (v1, \ldots,)$ denotes the set of wireless nodes and Edenotes a set of directed communication links. A set V of N node is distributed on ℵ.Each node v Є V can obtain its location *Loc (v)* on ℵ using a lower power GPS. Consider a controlled topology *G (V)*; the transmission radius and degree of a node v in *G (V)*are defined, respectively, as

$$T_u(G(V)) = \max_{uv\in(G(V))} D_{i,j} \quad (3)$$

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To collect the information of every mobile node in MANET is very difficult. Thus, it is desirable to propose a distributed algorithm, which usually requires only local knowledge, and the algorithm is run at every node in parallel. As a result, each node in the MANET is answerable for managing the links to all its neighbors only. If all the neighbor links are conserved, the end-to-end connectivity is acknowledged. In this scenario, Node v is allowable to communicate with its neighbors directly within 1 hop. In this paper, connectivity or network connectivity is the average node connectivity of all nodes in the entire network.

3. 1. Problem Formulation

The traditional methods stated in literature have improved the network capacity using topology control with cooperative communications. The existing topology control scheme tried to minimize the transmission power of nodes and preserve the given connectivity. However, energy consumption has not been considered and the network capacity has been improved significantly. Therefore, the goal of this paper is to minimize the transmission power while increasing the connectivity. To afford the optimal solution, this paper propose two routing algorithms namely 1) Non Cooperative Routing scheme (NCR) and 2) Cooperative Routing (CR) scheme. Comparison among the proposed algorithms helps to ensure the efficient of CC for assuring minimized transmission power and higher network connectivity. Furthermore, performance of the proposed algorithms is compared with existing approaches in simulation results section. The proposed algorithms are explained in the section 4.

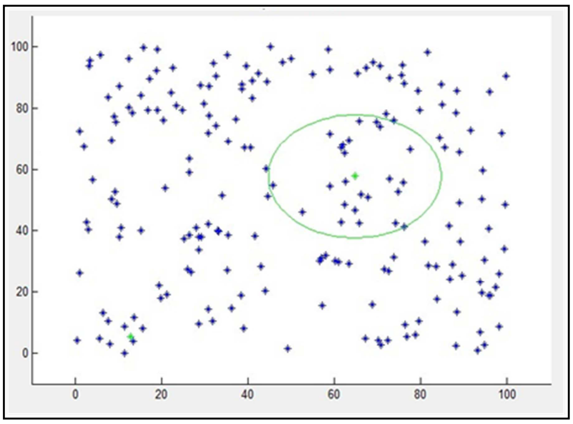

Fig.2. Transmission range of source node

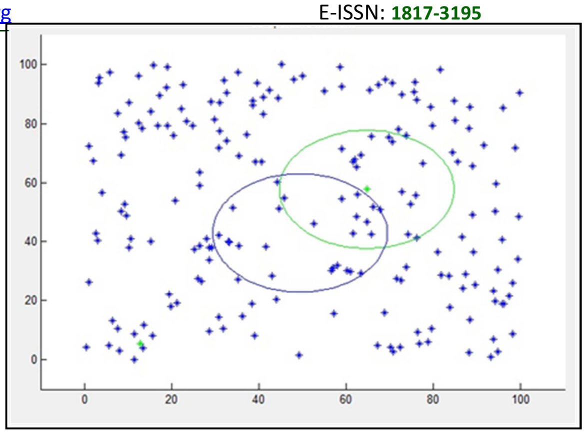

Fig.3.r-neighborhood region of source node

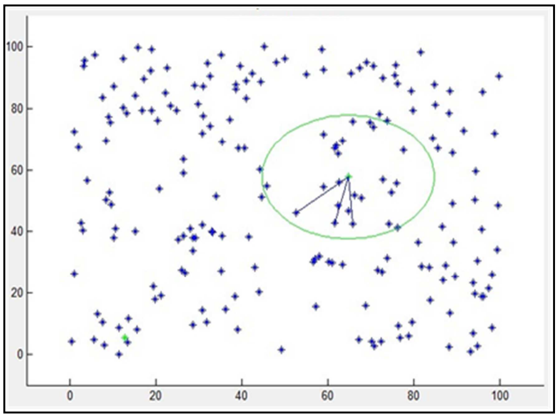

Fig.4. Helper nodes of source node

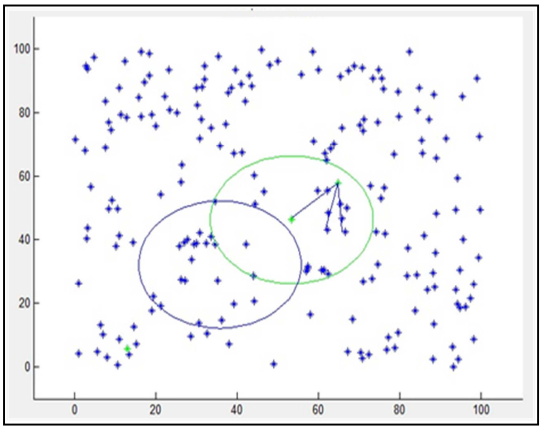

Fig.5. Transmission Range of Helper node

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4. PROPOSED METHOD

We have adopted the flexible structure, called the r-neighborhood [9] graph to our proposed work. Let consider the two nodes u and v, and a parameter $0 \leq r \leq 1$, we define the region intersected by two open circles centered, respectively, at u and v with the radius of their distance $D_{u,v}$ and an open circles centered at the middle point m with the radius $l = \left(\frac{D_{u,v}}{2}\right) * (1 + 2r^2)^{1/2}$ as the r-neighborhoodregion of u and v, represented as $NR_r^*(u,v)$.The general r-neighborhood region of u and v is defined using eq.4

$$NR_r^*(u,v) = \begin{cases} x \in \aleph : D_{u,x} < D_{u,v}, \\ D_{v,x} < D_{u,v}, \\ P(uxv) < P(uv)(1 + r^{\alpha}). \end{cases} \quad (4)$$

The r-neighborhood graph of a set of nodes V, denoted as $NG_r^*(v)$, consists of anedge uv if and only if $NR_r^*(v)$ contain no other node in V. The energy consumption of packet transmission between nodes and routes in this graph can be balanced by adjusting the parameter r. By increasing r, the radius and degree of each node become smaller. Nevertheless, the r-neighborhood graph was mainly introduced for stationary nodes and it should provide more attention to nodes' mobility when applied to mobile environments (MANET).

Initially, the proposed methods select a source and destination node to transmit the packet. Then source node estimates r-neighborhood region and links with neighbor nodes that presented in the r-neighborhood region using direct communication with the maximum transmission power. Every node measures the current position using GPS or localization methods and exchanges the position information with other nodes in the transmission region. After the measuring the r-neighborhood is over, each node communicates the request message to other nodes which are out of r-neighborhood region by using all neighbor nodes as intermediate nodes and helper nodes in NCR and CR respectively.

4.1. Cooperative communication Routing (CR):

First, a source node s and destination node v is taken from the network. Transmission range of the source node s is shown in Fig.2. Calculation of r-neighborhood region of source node s, as in Fig.3, is presented using eq.4 to select the 1-hop helper nodes. A source node can utilize C only after sending a request message to neighbor nodes through direct communication. The minimum transmission power of source node s, which consists of P^d and P^c for direct and cooperative communication, is as follows.

$$\max_{i \in H(s)} P_s^d = \frac{\tau}{(\max_{i \in H(s)} d_{si})^{-\alpha}} \quad (5)$$

$$P_{s \cup H(s)}^c(v) = P_\beta^c(v) = \frac{\tau}{\sum_{i \in \beta}^{n} (d_{iv})^{-\alpha}} \quad (6)$$

To add neighbor node i as a helper node of s, let b_i be the amount of powersaving that a source node can attain from adding helper node i in order to maintain a CC link, and let c_i be the consumed energy that the source node communicates with i directly. Given sourcenode u and destination node v, b_i and c_i can be attained by the following equations:

$$b_i = P_u^d(v) - P_{u \cup i}^c(v) = \frac{\tau}{(d_{uv})^{-\alpha}} - \frac{\tau}{\sum_{\beta \in \{u,i\}} (d_{\beta v})^{-\alpha}} \quad (7)$$

$$c_i = P_u^d(i) = \frac{\tau}{(d_{ui})^{-\alpha}} \quad (8)$$

After, selecting a set of helper nodes from the r-neighborhood region of source node, the same process is taken until the CC link reaches the destination. Since, multi-hop helper nodes employed in the transmission from a source to destination node, every helper node set receives the transmitted data from the set of helper nodes. Finally, the transmission data is decoded from the node, which has minimum path loss and minimum energy using eq.8.Non-Cooperative communication Routing, NCR is also similar to the CR where CC is not applied in the transmission of data from a source node to destination node. Therefore, it considers the 1-hop neighbor as the intermediate nodes and selection of these nodes are based on the remaining energy using eq.7.

5. SIMULATION RESULTS

We have proposed two routing algorithms, which ensure energy efficiency by allocating suitable CC links, and which increase and maintain the higher network connectivity. In this section, we perform extensive simulations to compare the performance of the proposed energy-efficient routing algorithms with and without cooperative communication (CR, NCR) with other

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schemes(Coop. Bridges, Coop. Bridges + DTCC, Max-Power-w/o-CC, Max−Power−w/−CC, DTCC and MST)[11]. The aim of topology control is to increase the network connectivity among as many nodes as possible while minimizing the power consumption of each node.

As a result, we consider the average transmission power as the simulation parameter for comparison of energy efficiency with other existing methods. To evaluate the connectivity; we use the network connectivity which is defined in section 3. Furthermore, we evaluate the connectivity-power-ratio (the ratio of network connectivity to average transmission power). In this simulation, 50-200nodes are randomly arranged. The path loss factor, α is set to 2 and 4. The value of P_{MAX} is 4900 and 24010000 for each value of α. For simulation suitability, the SNR threshold, we take Ʈ =1. Fig.6 shows that the comparison of average power consumed for a transmission from a source node to destination node. When alpha is 2,$P_{MAX}$is minimum and initial power of every node is minimum. Comparison between the NCR and CR is depicted in Fig.6 and observes that the average transmission power is minimized when we utilize the CC links, which is very smaller than the NCR algorithm.

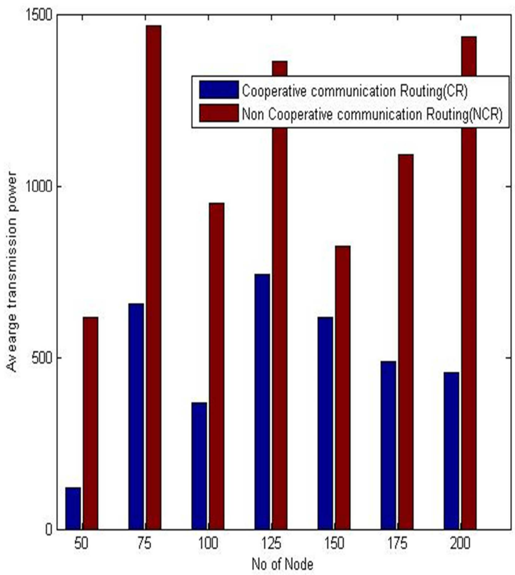

Fig.6. Comparison of average transmission power between NCR and CR (α = 2).

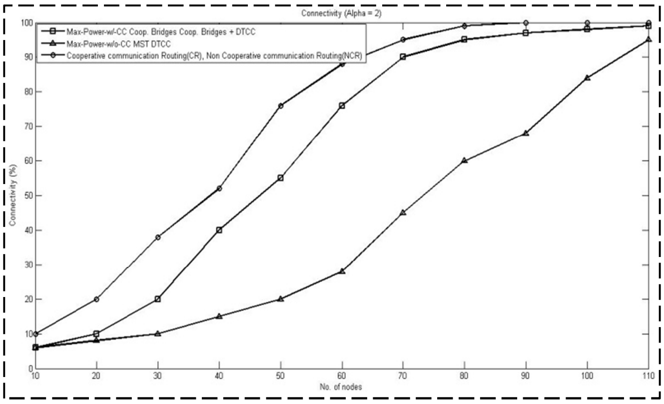

Fig.7. Comparison of connectivity percentage (α = 2).

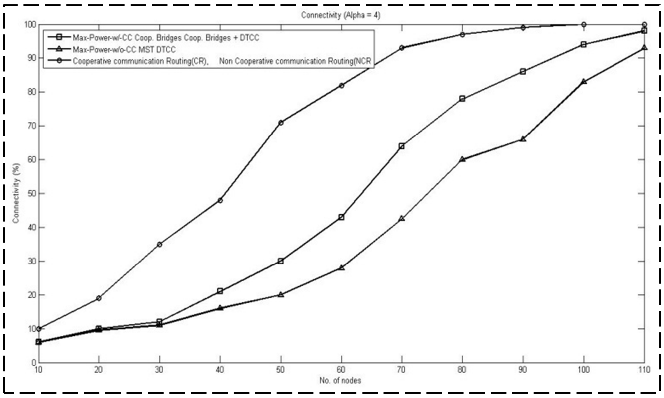

Fig.8. Comparison of connectivity percentage (α = 4).

To evaluate the proposed NCR and CR algorithms with existing methods, we reduce the number of nodes as 10-110. In Fig.7 and Fig.8, the network connectivity with respect to an increase in the number of nodes is compared. The path loss factor α is set to 2 and 4 in Fig.7 and Fig.8, respectively. It is observed that as the number of nodes increases, the network connectivity also increases. In proposed NCR and CR methods, as each node can form the communication link with more nodes via CC among whole network area, the network connectivity in CR and NCR has a greater rate of increase than that of Max-Power-w/-CC, Coop. Bridges and Coop. Bridges + DTCC, MST, DTCC, and Max-Power-w/o-CC. This difference of connectivity performance between schemes tends to be increased when is 2 rather than 4.This occurrence imitates the fact that the frequency of connecting all the nodes by CC is reduced if the path loss factor α is increased.

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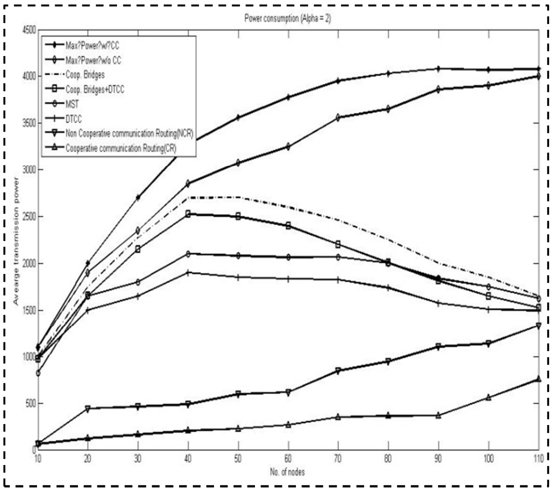

Fig.9. Comparison of Power consumption (α = 2).

Fig.9 and Fig.10 compare the transmission power consumption or energy consumption of various methods when the number of node increases. The value of α is 2 and 4 in Fig.9 and Fig.10 respectively. This shows that our proposed CR algorithm does not require high power consumption compared to the NCR, all other existing methods with and without using CC.

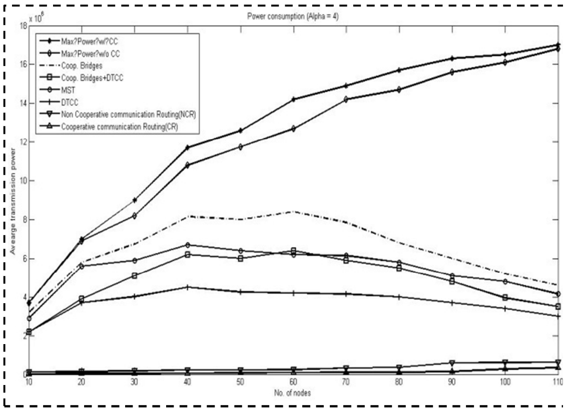

Fig.10. Comparison of Power consumption (α = 4).

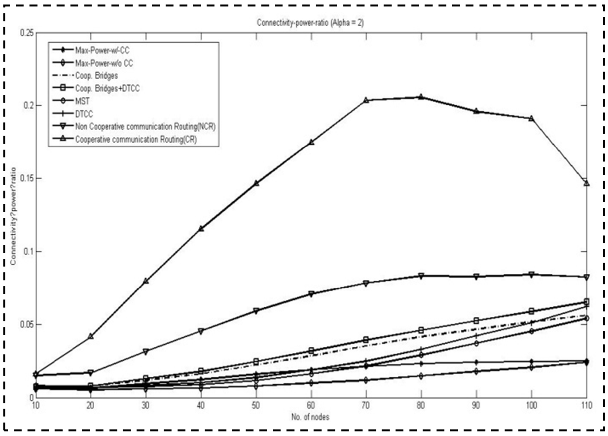

Fig.11. Comparison of Connectivity-power-ratio (α = 2)

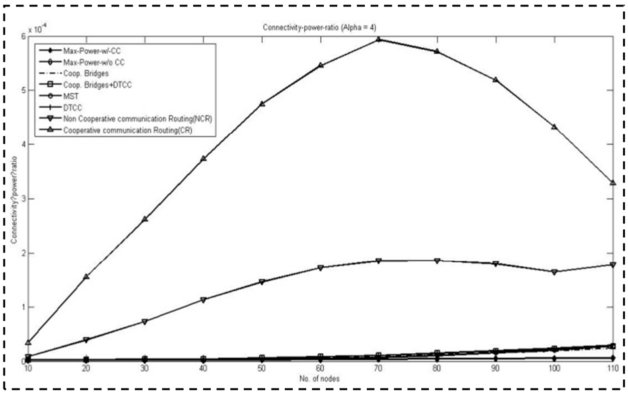

Fig.12. Comparison of Connectivity-power-ratio (α = 4).

Fig.11 and Fig.12 shows the connectivity-power-ratio of the proposed CR and NCR methods with existing algorithms, where α is 2 and 4, respectively. The performance of CR is higher than the all other methods in Fig.11 and Fig.12.The comparison of connectivity-power-ratio between the various schemes shows that the proposed CR algorithm has the best performance among the considered topology control schemes. However, the proposed NCR and CR algorithms are energy efficient and provide higher network connectivity when compared with other techniques.

6. CONCLUSION

In this paper, we have proposed an energy efficient routing algorithm with topology control scheme using cooperative communication to minimize the transmission power of nodes and increase connectivity for entire networks. This paper was mainly focused on providing minimum energy consumption for the nodes in MANET. The

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proposed method works on physical layer with cooperative communication. We have proposed two routing algorithms: 1) Non Cooperative Routing scheme (NCR) and 2) Cooperative Routing (CR) scheme. The r-neighborhood region of the node has been utilized to select intermediate and helper nodes in the NCR and CR methods respectively. Then selection of relay node in CR scheme was presented based on transmission power and residual energy. This paper has elected the multi-hop relays as helper nodes in cooperative communication. In simulation results, the proposed algorithms were compared with existing cooperative algorithms to prove the efficiency of our proposed method. CR method was minimized the transmission power and percentage of connectivity than the other algorithms including NCR. Thus, the energy efficiency of the proposed method was proven from the presented simulation results.

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