CHAPTER 3

EFFICIENT BROADCASTING WITH REDUCED ENERGY USING COOPERATIVE COMMUNICATION

3.1 INTRODUCTION

A key consideration for any energy efficient protocol is the energy consumption at a wireless node. With respect to network activities (i.e. ignoring energy consumed in lighting up a display, power a hard drive, etc.) each node’s radio can be in one of the following three states.

- **Transmitting**: The node is transmitting messages with transmission power $P_t$.
- **Receiving**: The node is receiving messages with reception power $P_r$.
- **Idle**: When no message is being transmitted, the node stays idle and keeps listening to the medium, consuming energy at a rate that corresponds to a power level $P_{idle}$.

$$P_{idle} < P_r < P_t$$

Resource limitation, mobility of hosts and changing of wireless link make it difficult for MANET to manage all quality of services. In a situation of greater mobility, there will be many topology changes and so more control packets are required. Methods to reduce energy consumption include:
• Considering residual battery energy while selecting the route.

• Reducing the communication overhead of control messages.

• Efficient route reconfiguration mechanisms (effect in topology changes)

Total energy consumption is divided into two parts: $E_{\text{path-discovery}}$ and $E_{\text{path-txion}}$. $E_{\text{path-discovery}}$ is directly proportional to the number of control packets. The principal sources of energy waste in MAC assume collision, message overhearing and control packet overhead and idle listening.

$$E_{\text{total}} = E_{\text{path-discovery}} + E_{\text{path-txion}}$$

$E_{\text{path-discovery}} \propto \text{control-packets}$

$$E_{\text{path-txion}} = E_{\text{idle}} + E_{\text{active}} + E_{\text{sleep}} + E_{\text{transient}}$$

$E_{\text{active}} = E_{\text{receive}} + E_{\text{transmit}}$

$E_{\text{sleep}} = 0$

To increase node and network lifetime, the route is established by taking the lightly loaded nodes with sufficient power resources. For longer network life and minimized energy consumption, the following approaches are suggested.

• Power management Approach

• Power Control Approach

• Topology Control Approach

Minimization of energy consumption of a path can be obtained by

• Minimum total transmission power
- Minimum total transceiving power
- Minimum total reliable transmission power

3.1.1 DEAR Protocol

DEAR stands for Device and Energy Aware Routing. DEAR protocol explains the use of device awareness to enhance energy efficiency in the routing. A node is assumed to be device aware if it is assumed to be powered by two states: internal battery power and external power source. It assumes that the cost of a node powered by the external source is zero. The packets can be redirected to the powered node for power saving operations. An externally powered node has rich resource of power. It is capable of increasing its transmission power to a higher level so that it is easily reachable to any desired node in the network in one hop distance. DEAR provides power saving by eliminating a number of hops, which increases system lifetime, also average delay in packet receiving is minimized.

3.1.2 SPAN Protocol

Nodes in idle mode unnecessarily consume energy. To save energy, it is better to put those nodes in sleep state without hampering network connectivity. For taking this decision, a master node is selected. The SPAN protocol employs a distributed approach to select a master node. The rule says that if two of its neighbors cannot reach each other either directly or via one or two masters, it should become a master. This rule does not yield the minimum number of master nodes. It provides robust connectivity with substantial energy savings. However, the master nodes are easily overloaded. To minimize this, the master node at any time withdraws as a master. It gives its neighbor node a chance to become a master if it satisfies master eligibility criteria.
3.1.3  XTC Protocol

The XTC topology control algorithm works without either location or directional information. The algorithm has three phases. In the first one, each node broadcasts at maximum power. Then, it ranks its entire neighbor depending upon its link quality to it. The link quality could be the Euclidean distance, signal attenuation or packet arrival rate depending on various situations. In the second step, each node transmits its ranking results to the neighboring nodes. In the final one, each node examines the ranking results of its neighbors. Depending upon this result, it selects its neighbor to be linked directly. The XTC algorithm follows both symmetry and connectivity feature of topology control. It runs faster compared to other algorithms.

3.1.4  LFTC Protocol

The LFTC protocol constructs power-efficient network topology. It also avoids any potential collision due to hidden terminal problem. It works in two phases: link determination phase and interference announcement phase. In the first phase, each node broadcasts hello message with vicinity table. This table is attained by every other node in the network. Each node adjusts its transmission power $P_{\text{data}}$ to communicate with all its direct neighbors. The set of its direct neighbors is called direct communication set (DCS). The second phase avoids data collision due to hidden terminal problem. This is done by taking appropriate power for $P_{\text{data}}$ and $P_{\text{control}}$. This results in two simultaneous data transmission in networks without any interference. The LFTC protocol has smaller hop count, low control packet overhead and low ratio of collision compared to XTC.

3.1.5  Energy Dependent DSR (EDDSR)

EDDSR is energy dependent DSR algorithm which helps a node from sharp and sudden drop of battery power. EDDSR provides better power
utilization compared to LEAR (Least Energy Aware Routing) and MDR (Minimum Drain Rate). EDDSR avoids use of node with less power supply, and the residual energy information of the node is useful in the discovery of the route. Residual power of each node is computed by itself, and if it is above the specific threshold value, then the node can participate in routing activities, otherwise the node delays the rebroadcasting of route request message by a time period which is inversely proportional to its predicted lifetime. EDDSR has further advantage over MDR because it can use route cache used by DSR.

3.1.6 Location Based Energy Aware Routing Protocols and Algorithms

LAR (Location Aided Routing) protocol is one of the most important and popular geographical-based routing protocol for wireless mobile ad hoc networks. LAR is based in sensible flooding. In flooding, the source node broadcasts the route request to its neighbors. These nodes check their identification with the destination. If a match occurs, destination is found; otherwise they re-broadcast the message to their neighbors. Whenever any node gets the broadcast for the first time, it re-broadcasts it. So, broadcast moves outwards from source and this broadcast is terminated when every node has got the message and transmitted it once.

LAR applies the concept of expected zone and request zone. The expected zone is the area where the destination node can be found calculated with the help of its location information and speed. Additional information like direction of movement can help in reducing the size and increasing the accuracy of the expected zone. Request zone includes expected zone as well as other regions around the expected zone. Route request can be forwarded by those nodes which only belong to this request zone. So, a restriction on flooding is applied to increase the efficiency of the protocol.
3.1.7 Topology Control

Mobility of wireless nodes makes the topology of network changes temporary. It is affected by many uncontrollable factors like node mobility, weather conditions, environmental interference and obstacles and some controllable factors like transmission power, antenna direction and duty cycle scheduling. Topology of network is considered as graph with its nodes as vertices and communication links between node pairs as edges. The edge set is large possible one if communication is established by the node's maximum transmission power. In dense network, too many links lead to high energy consumption. The primary target of topology control is to replace long distance communication with small energy efficient hops. Dense network ensures tight connectivity and high interference. In sparse network, connectivity between nodes is a question. So, there is a tradeoff between network connectivity and sparseness. Network topology can enhance network throughput because of two benefits. First, the interference is reduced if transmission radii of nodes are reduced to the near one. Second, more data transmission is carried out simultaneously in the neighborhood of a node. A bad network topology has many adverse effects such as low capacity, high end-to-end delay and weak robustness to node failure whereas a good network topology minimizes energy consumption and end-to-end delay without much affecting the throughput.

The simulated results of co-operative communication scheme for efficient broadcasting are

- The percentage of connectivity of the network
- Average transmission power of the node in the network
- Connectivity power ratio at different power consumption levels
• Average transmission power at different power consumption levels

3.2 PROBLEM FORMULATION

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 work is to minimize the transmission power while increasing the connectivity. To afford the optimal solution, this work proposes two routing algorithms, namely 1) Non-Cooperative Routing scheme (NCR) and 2) Cooperative Routing (CR) scheme. A comparison among the proposed algorithms helps to ensure the efficiency of CC for assuring minimized transmission power and higher network connectivity.

3.3 PROPOSED METHOD

Consider the two nodes u and v, and a parameter 0 \leq r \leq 1, 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 centred at the middle point \( m \) with the radius \( 1 = \left( \frac{D_{u,v}}{2} \right)^2 \) as the r-neighbourhood region of u and v, represented as \( NR_r^*(u,v) \). The general r-neighborhood region of u and v is defined using Equation (3.1)

\[
NR_r^*(u,v) = \begin{cases} 
\forall x \in V : D_{u,x} < D_{u,v}, \\
D_{v,x} < D_{u,v}, \\
P(uvx) < P(uv)(1 + r^a)
\end{cases}
\]  

(3.1)

The r-neighborhood graph of a set of nodes V, denoted as \( NR_r^*(v) \), consists of an edge u v if and only if \( NR_r^*(v) \) contains 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 becomes 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, the source node estimates $r$-neighborhood region and links with neighbor nodes that are present 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 measuring the $r$-neighborhood is over, each node communicates the request message to the 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. Figure 3.1 shows the simulated network with 200 nodes.

![Figure 3.1 System model of the simulated Network](image-url)
3.3.1 Cooperative communication Routing (CR)

Transmission range of the source node \( s \) is shown in Figure 3.2. Calculation of \( r \)-neighborhood region of source node \( s \), as in Figure 3.3, is presented using Equation (3.2) to select the 1-hop helper nodes. A source node can utilize \( C \) only after sending a request message to the 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.

\[
\max_{i \in H(s)} P^d_i = \frac{T}{\max_{i \in H(s)} d_{si}}^{\alpha}
\]

(3.2)

\[
P^c_{\text{sup}(y)}(y) = \frac{T^l}{\sum_{i \in H(s)} d_{iy}^{\alpha}}
\]

(3.3)

![Figure 3.2 Transmission range of source node](image)

Figure 3.2 Transmission range of source node
Figure 3.3 r-neighborhood region of source node

To add neighbor node \( j \) as a helper node of \( s \), let \( b_j \) be the amount of power saving that a source node can attain from adding helper node \( j \) in order to maintain a CC link, and let \( c_j \) be the consumed energy that the source node communicates with \( j \) directly. Given the source node \( u \) and the destination node \( v \), \( b_j \) and \( c_j \) can be attained by the following equations:

\[
b_j = P_u^c(v) - P_{u|j}^c(v) = \frac{T}{(d_{uv})^{-\alpha}} - \frac{T}{\sum g_{lj}(d_{lj})^{-\alpha}} \tag{3.4}
\]

\[
c_j = \frac{P_u^c(l)}{(d_{ul})^{-\alpha}} \tag{3.5}
\]

After selecting a set of helper nodes from the r-neighborhood region of the source node, the same process is taken until the CC link reaches the destination. Since multi-hop helper nodes are employed in the transmission from a source to a 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 Equations (3.4) and (3.5). 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 a destination node. Therefore, it considers the 1-hop neighbor as the intermediate nodes and selection of these nodes are is based on the remaining energy using Equations (3.4) and (3.5).

3.4 SIMULATION RESULTS

The proposed two routing algorithms, ensure energy efficiency by allocating suitable CC links, and which increase and maintain the higher network connectivity. In this section, extensive simulations are performed to compare the performance of the proposed energy-efficient routing algorithms with and without cooperative communication (CR, NCR) with other schemes (Coop. Bridges, Coop. Bridges + DTCC, Max-Power-w/o-CC, Max–Power–w/-CC, DTCC and MST). 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.

Table 3.1 Simulation Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of nodes</td>
<td>200</td>
</tr>
<tr>
<td>Mobility</td>
<td>2.5m/s</td>
</tr>
<tr>
<td>Routing protocol</td>
<td>CR, NCR</td>
</tr>
<tr>
<td>Path loss factor</td>
<td>$\alpha = 2&amp;4$</td>
</tr>
<tr>
<td>Traffic</td>
<td>CBR</td>
</tr>
<tr>
<td>Simulation time</td>
<td>10 min</td>
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</tbody>
</table>
As a result, the average transmission power is considered as the simulation parameter for the comparison of energy efficiency with other existing methods. To evaluate the connectivity, we use the network connectivity is used, which is defined in section 3.3.1. Furthermore, the connectivity-power-ratio (the ratio of network connectivity to average transmission power) is evaluated. In this simulation, 50-200 nodes are randomly arranged. The path loss factor, $\alpha$ is set to 2 and 4. The value of $P_{\text{MAX}}$ is 4900 and 24010000 for each value of $\alpha$. For simulation suitability, the SNR threshold is considered, we take $\gamma = 1$. Figure 3.4 shows the comparison of average power consumed for a transmission from a source node to a destination node. When alpha is 2, $P_{\text{MAX}}$ is minimum and the initial power of every node is minimum. Comparison between the NCR and CR is depicted in Figure 3.4 and it is observed that the average transmission power is minimized when we utilize the CC links are used, which is very smaller than the NCR algorithm.

![Figure 3.4](image)

**Figure 3.4** Comparison of average transmission power between NCR and CR ($\alpha = 2$)
To evaluate the proposed NCR and CR algorithms with the existing methods, the number of nodes is reduced as 10-110. In Figure 3.5 and Figure 3.6, the network connectivity with respect to an increase in the number of nodes is compared. The path loss factor $\alpha$ is set to 2 and 4 in Figure 3.5 and Figure 3.6 respectively. It is observed that as the number of nodes increases, the network connectivity also increases. In the 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 \( \alpha \) 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 \( \alpha \) is increased.

![Figure 3.7 Comparison of Power consumption (\( \alpha = 2 \))](image)

Figure 3.7 and Figure 3.8 compare the transmission power consumption or energy consumption of various methods when the number of node increases. The value of \( \alpha \) is 2 and 4 in Figure 3.7 and Figure 3.8 respectively. This shows that the proposed CR algorithm does not require high power consumption compared to the NCR, all other existing methods with and without using CC.
Figure 3.9 and Figure 3.10 show the connectivity-power-ratio of the proposed CR and NCR methods with the existing algorithms, where $\alpha$ is 2 and 4, respectively. The performance of CR is higher than that of all other methods in Figure 3.9 and Figure 3.10. 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.

Figure 3.8 Comparison of Power consumption ($\alpha = 4$)
3.5 CONCLUSION

The comparison of connectivity-power-ratio and power consumption 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. CR algorithm was mainly focused on providing minimum energy consumption for the nodes in MANET. The r-neighborhood region of the node has been utilized to select intermediate and helper nodes in the NCR and CR methods respectively. Then, the selection of relay node in CR scheme was presented based on transmission power and residual energy. Here, selected the multi-hop relays as helper nodes in cooperative communication. CR method was minimized the transmission power and percentage of connectivity compared with the other algorithms including NCR. By using cooperative communication method more connectivity and less power consumption can be obtained.