Energy Efficient Topology Based on Demand for MANETS Using Directional Antenna

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Abstract: Energy efficient topology in Ad-hoc networks can be achieved mainly in two different ways. In the first method, network maintains a small number of nodes to form a connected backbone and the remaining nodes sleep to conserve energy. This method is effective for low traffic networks. Energy efficiency in the second method is achieved by power control technique. This technique is effective in high traffic conditions. In order to reduce the energy consumption for mobile ad hoc network the topology is dynamically adjusted for various network traffic conditions. The simulation of DBET protocol will be carried out using Ad hoc On-demand Distance Vector (AODV) as a routing protocol in a network simulator. We have simulated protocol DBET by using AODV [1] as routing protocol in network simulator ns2.33 [2] and compared with AODV and energy consumption while using omnidirectional and directional antennas is also compared. The simulation studies revealed that the proposed scheme perform better in terms of energy, delay and delivery ratio and using directional antenna energy consumption is further reduced.

Key words: Energy efficient topology • Routing • MANET • Directional antenna. DBET (Demand Based Energy Efficient Topology for MANETs)

INTRODUCTION

Mobile Ad-hoc Networks (MANETs) are self-organizing, self-configuring and infrastructure-less multi-hop wireless networks, where each node communicates with other nodes directly or indirectly through intermediate nodes without any infrastructure. Besides these characteristics they present challenges like limited energy, dynamic topology, low bandwidth and security. The description of the arrangement of the MANETs, called topology, is usually temporary or dynamically changed with time. Energy conserving is one of the challenges because of limited battery resource. The techniques which are used to reduce the initial topology of network to save the energy and increase the lifetime of network, with the preservence of network connectivity, called topology control techniques. Various techniques, in network layer, are proposed in the literature to conserve energy. These techniques can be classified mainly into two categories: by controlling the number of nodes with the smaller link cost. In the first method a small number of nodes awake to maintain the network connectivity and remaining nodes go into sleep state to conserve energy. This method is effective in low traffic conditions, because the power consumption to keep nodes awake dominates the power consumption in data transfer. In the second method, topology is controlled by keeping lesser cost links in the network. This method is effective in high data traffic because power consumption in data transfer dominates the power required to keep nodes awake. We combine the advantages of these two techniques to dynamically adjust network topology for various network traffic conditions. Directional antennas are traditionally used in cellular wireless networks to increase the network capacity [3]. A cellular system using directional base station antennas can have a smaller distance between co-channel cells than a system using omnidirectional antennas, thereby achieving a higher degree of spatial reuse of spectrum. Mobile ad hoc networks can potentially gain similar capacity advantages by using directional antennas. Since all nodes are mobile, in order to use directional antennas for communication the nodes need to dynamically estimate the direction of its neighbors and also follow an efficient protocol for orienting its direction for transmission and reception. In addition to the advantage of reducing unwanted
interference, directional antennas have the property that its peak gain is higher than that of a similar antenna with an omnidirectional pattern. This characteristic can be utilized to reduce the power of a transmitter when it is using a directional antenna. The rest of the paper is organized as follows: the next section provides a brief review of related studies. The third section gives the design details of DBET protocol, usage of directional antenna is discussed in the forth section. Simulation results along with discussions are provided in the section 5. The last and final section concludes the paper with same pointers to future research direction.

**Related Work:** The possibility of benefiting from directional transmissions in packet radio networks was first proposed in [4], where a slotted ALOHA packet radio network was considered. Thereafter, several studies were presented on designing MAC protocols for using sectorized and beam forming directional antennas in MANETs. The use of more advanced beam forming antennas in place of sectorized directional antennas in ad hoc networks is considered in. The authors assume prior knowledge of location information and use directional transmission of RTS and CTS packets. They presented the study of two collision avoidance schemes, one being more aggressive than the other, for blocking transmissions from listening nodes that receive an RTS or a CTS packet. Li and Wan [5] described a distributed protocol to construct a minimum power topology and developed an algorithm which directly find a path whose length is within a constant factor of the shortest path. The length of the path is measured in term of energy consumption. This proposed algorithm used only local information. An energy efficient dynamic path is maintained to send data from source to destination for MANET is proposed in Sheu, Tu and Hsu [6]. Due to mobility existing paths may not be energy efficient. So, each node in a data path dynamically updates the path by adjusting its transmission power. Each node in the networks determines its power for data transmission and control packets transmission according to the received beacon messages from its neighbors. In dynamic path optimization technique protocols dynamically select energy efficient path as per the requirement of dynamic topological changes in the network [7].

**Preliminaries**

**Directional Antennas:** Typically the gain of an antenna is described as a function of the horizontal angle $\theta$ and the vertical angle $\varphi$ from a fixed line of reference. For an omnidirectional antenna, the gain is invariant with respect to the angle $\theta$, whereas a directional antenna has a higher gain for a range of values of $\theta$ known as the main lobe and lower gain in other directions. Antennas used in terrestrial wireless communication usually have a vertical beam pattern lying within a certain range of values of $\varphi$ close to the horizontal plane that is identical for all values of $\theta$. The beamwidth of a directional antenna is described as the horizontal angular variation (variation of $\theta$) within which the gain of the antenna is not lower than 3 dB of the maximum gain of the antenna. For a sectorized antenna, this beam is oriented towards a fixed direction.

**Demand Based Energy Efficient Topology:** In this section, we present demand based energy efficient topology (DBET) for mobile ad hoc network, which dynamically changes the topology according to the network traffic requirements. Initially we compute a small set of nodes, which form a connected backbone, while the other nodes are put off to conserve energy. This connected backbone is used for routing the packets under low network load. When there is a bulk data transfer between a pair of nodes, the topology dynamically changes along the path between these nodes by power control and route optimize technique to minimize the power consumption. The DBET can be divided into four phases. The first phase selects a small set of nodes that constitutes an independent set of the network. The second phase is responsible for electing more nodes to ensure that the selected nodes form a connected backbone. Remaining nodes go to sleep to conserve energy. Active node withdraw process is implement in the third phase to remove redundant nodes in each region. To improve the performance along the high traffic path we use the route optimization with power control technique in the fourth phase. In this technique, we change topology dynamically to connect more nodes, around the routing path to minimize the total power consumption.

**Energy Conservation**

**Transmit Power Issues:** Since a directional antenna has a higher gain, a transmitter using directional antennas requires a lower amount of power to transmit to the same
distance as would be needed with an omnidirectional antenna. Hence, transmitting nodes can conserve power by adequately reducing the transmit power when using directional transmissions. In this paper, we assume that for a given transmission distance, the power required by a transmitter using a directional antenna is proportional to its beamwidth. This implies that a source using a directional antenna with 90 degrees beamwidth will require 1/4 the amount of power as that needed with an omnidirectional antenna to transmit to the same destination. Note that the gain of a directional antenna should also be taken into account for receiving and carrier sensing with directional antennas. However, we do not consider the power consumed for these receiver operations in this work. We assume that nodes automatically control the transmit power when using a directional antenna such that the transmission distance is maintained constant. Furthermore, we also consider a power control scheme, where the transmission power is reduced by an additional factor that is based on the minimum SINR required at the destination.

**Integrating DBET with Routing Protocol:** The DBET can be integrated with any routing protocol. In this section, we discuss the process of integration with AODV. In our approach all control packets and data packets are transmitted on low traffic path with full transmission power and data packets on high traffic path with minimum required energy.

**Route Discovery:** Route discovery uses route cost in place of hop count as route metric. We use the notation $d_{I,J}$ denotes the cost of least cost path from the node $I$ to the node $J$.

When a source node $S$ wants to find a route to a destination $D$, it broadcasts the route request packet (RREQ) to its neighbors. The route request packet contains the least route cost from source node $S$, which is initially zero. An intermediate node $J$ receiving the route request packet from another intermediate node $I$, it calculates the cost of the path form node $S$ to nodes $J$ as $d_{S,I} + d_{I,J}$. The node $J$ update its routing table if the calculated cost is less than the cost in its routing table and forward the route request packet to its neighbors with updated cost. In order to avoid another cost update, node $J$ waits for the time (propositional to the cost to $d_{S,J}$) before forwarding. When a destination node $D$ receives first route request packet (RREQ), it calculates the route cost and update its routing table. It waits for a fixed time interval to receive more route request packets and find the least cost route among them. The node $D$ unicasts a route reply packet (RREP) back to its neighbor from which it received the least cost route. The neighbor nodes unicast RREP towards the source node $S$.

**Local Route Customization:** As we discussed earlier due to the dynamic nature of the network new node may come closer to existing path, which may reduce the existing route cost, if it participates in forwarding the data.

Let consider the example network given in the Fig. 1(a) with the existing path cost from the node $I$ to the node $J$ is 9 units. If a node is in data transmission path, it sends the

$<\text{Source address, Destination address, Route cost from source to itself}>$ as a piggyback with periodic hello messages in full transmission path. After receive the hello messages from the node $I$ and the node $C$, along with piggyback information, node $X$ calculate the link cost $d_{I,X}$ and $d_{C,X}$ and checks whether it can participate in the ongoing data transfer. The node $X$ can participate in data forwarding, if it reduces the cost of the path from the node $I$ to the node $C$. That is, if $d_{I,X} + d_{C,X} < d_{I,C}$ then the new node $X$ participate in the routing by sending route update control message (RUP) to the node $I$ and the node $C$ with route cost $d_{I,C}$. When the node $I$ and the node $C$ receive (RUP) messages and then update their routing tables.

**Performance Evaluation:** We have evaluated the performance of DBET with AODV [2] as a routing protocol and compared with AODV and have also compared the energy consumption of directional and omnidirectional antennas using the network simulator NS2.33.

**End-to-end Delay:** The end-to-end delay is the average time between data packets sent out from the sources and received at the destination. The figure (2) shows the delay with respect to time. In high network load the DBETs performance is better than AODV. This is because the low transmission power implies low queuing delay and reduced interference.
Table 1: simulation parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation Time</td>
<td>500 sec</td>
</tr>
<tr>
<td>Number of Nodes</td>
<td>38</td>
</tr>
<tr>
<td>Max node energy</td>
<td>1000J</td>
</tr>
<tr>
<td>Energy distribution</td>
<td>Normal Distribution</td>
</tr>
<tr>
<td>MAC</td>
<td>IEEE 802.11</td>
</tr>
<tr>
<td>Max Tx Power</td>
<td>0.75W</td>
</tr>
<tr>
<td>Max Rx Power</td>
<td>0.25W</td>
</tr>
<tr>
<td>Basic Routing Protocol</td>
<td>AODV</td>
</tr>
<tr>
<td>Propagation Model</td>
<td>Two Ray Propagation Model</td>
</tr>
<tr>
<td>Node Motion</td>
<td>Random Motion</td>
</tr>
</tbody>
</table>

**Packet Delivery Ratio:** Packet delivery ratio is the ratio of the data packets received at the destination to the data packets sent out from the sources. The Fig. 3 shows the overall delivery ratio with respect to the mobility rate. As the mobility rate increases, the delivery ratio always decrease.

**Energy Consumption:** Energy consuming while using DBET is less when compared to that of AODV.

**Energy Consumption in Directional and Omnidirectional Antenna:** The energy consumption while using directional and omnidirectional antennas are compared and it is found that while using directional antenna the energy is consumed less than omnidirectional antenna.

**CONCLUSION**

In this paper, we proposed a demand based energy efficient topology using directional antenna that dynamically adjusts its topology for various network traffic conditions. We have simulated the protocol DBET and compared with AODV and by using directional antenna. The simulation studies revealed that the proposed scheme perform better in terms of energy, delay, delivery ratio. The mobility in the nodes at high traffic conditions affects the packet delivery ratio which can be improved.

**REFERENCES**
