Energy Efficient Reliable Routing Considering Residual Energy in Wireless Ad Hoc Networks

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Abstract—Two novel energy-aware routing algorithms to be proposed for wireless ad hoc networks, called reliable minimum energy cost routing (RMECR) and reliable minimum energy routing (RMER). RMECR addresses three important requirements of ad hoc networks: energy-efficiency, reliability, and prolonging network lifetime. It considers the energy consumption and the remaining battery energy of nodes as well as quality of links to find energy-efficient and reliable routes that increase the operational lifetime of the network. RMER, on the other hand, is an energy-efficient routing algorithm which finds routes minimizing the total energy required for end-to-end packet traversal. RMER and RMECR are proposed for networks in which either hop-by-hop or end-to-end retransmissions ensure reliability. Simulation studies show that RMECR is able to find energy-efficient and reliable routes similar to RMER, while also extending the operational lifetime of the network. This makes RMECR an elegant solution to increase energy-efficiency, reliability, and lifetime of wireless ad hoc networks. In the design of RMECR, we consider minute details such as energy consumed by processing elements of transceivers, limited number of retransmissions allowed per packet, packet sizes, and the impact of acknowledgment packets. This adds to the novelty of this work compared to the existing studies.

Keywords— Energy Efficiency, Residual Energy, Wireless Ad hoc Networks.

I. INTRODUCTION

Ad Hoc Networks is defined as a collection of mobile hosts forming a temporary network without the aid of any centralized administration or standard support services. In Latin, ad hoc literally means "for this," further meaning "for this purpose only and thus usually temporary" [1]. Ad hoc networks represent complex distributed systems that comprise wireless mobile nodes that can freely and dynamically self-organize into arbitrary and temporary, “ad-hoc” network topologies, allowing people and devices to seamlessly inter-network in areas with no pre-existing communication infrastructure. The concept of Ad Hoc Networking has been around for nearly 20 years but has received renewed interest in the last 18 to 24 months [2].

In Ad Hoc Networks the individual mobile hosts (nodes) act at the same time as both the router and the host. An ad-hoc (or "spontaneous") network is a local area network or any other small network, especially one with wireless or temporary plug-in connections, in which some of the network devices are part of the network only for the duration of a communication session, whereas in the case of mobile or portable devices it is part of the network when in some close proximity to the rest of the network [1].

Ad Hoc Networks are future alternative to the current trend of connections among wireless devices via fixed infrastructure-based service.

Ad Hoc Networks are useful in areas that have no fixed infrastructure and hence need alternative ways to deliver services. Ad Hoc Networks work by having mobile devices connect to each other in the transmission range through automatic configuration, i.e., setting up an ad hoc network that is very flexible. In other words there is no intervention of any controller that goes ahead and gathers data from all nodes and organizes it. All data gathering and cross-node data transfer is taken care of by the nodes themselves [2].

Ad Hoc Networks are a major goal towards the evolution of 4G (Fourth generation) devices. In the nodes of the Ad Hoc Networks, computing power and network connectivity are embedded in virtually every device to bring computation to users, no matter where they are, or under what circumstances they work. These devices personalize themselves to find the information or software they need. The strife is to make use of all technologies available without making any major change to the user’s behaviour. There is also working going on to make the seamless integration of various networks possible, i.e., integration of LAN, WAN, PAN and Ad Hoc Networks. But there is still a lot of work to be done to make this completely possible. Node mobility in an ad hoc network causes frequent changes of the network topology [1].

II. RELATED WORK

Several routing protocols have been developed recently to address the energy efficiency issue. Sending data from source node to destination node is called routing. The routing can be done hop by hop or end to end. In hop by hop routing the intermediate nodes are used to route the data. Hop by hop routing is more efficient because in this technique the transmission or retransmission distance is shorter. Wireless Ad- Hoc network routing protocols normally specified in following types.

1. Proactive energy-aware routing: With table-driven routing protocols, each node attempts to maintain consistent, up-to-date routing information to every other node in the network.

2. Reactive energy-aware routing: With on-demand driven routing, routes are discovered only when a source node
desires them.

3. Hybrid energy-aware routing: In hybrid routing a well combination of proactive and reactive routing methods are used which are better than the both used in isolation. It includes the advantages of both protocols.

III. SYSTEM DESIGN

Wireless links in ad hoc networks are usually prone to transmission errors. This necessitates the use of retransmission schemes to ensure the reliability, HBH or E2E retransmissions can be used.

A. Routing in Wireless Ad Hoc Networks

Routing protocol supports the delivery of packets. It is the fundamental part of network infrastructure. Today network security has attracted more attention than before but the security concern for routing protocols has not been fully aware.

B. Hop-by-Hop and End-to-End Retransmission Systems

In the HBH system, a lost packet in each hop is retransmitted by the sender to ensure link level reliability. An acknowledgment (ACK) is transmitted by the receiver to the sender when it receives the packet correctly. If the sender does not receive the ACK, the sender retransmits the packet. In the E2E system, the ACKs are generated only at the destination and retransmissions happen only between the end nodes. The destination node sends an E2E ACK to the source node when it receives the packet correctly.

C. Routing in Wireless Ad Hoc Networks

Main objective is to find reliable routes which minimize the energy cost for E2E packet traversal. For this, reliability and energy cost of routes must be considered. The main aim is that energy cost of a route is related to its reliability. If routes are less reliable, the probability of packet retransmission increases. Thus, a larger amount of energy will be consumed per packet due to retransmissions of the packet.

D. Minimum Energy Cost Path

The minimum energy cost path (MECP) between a source and a destination node is a path which minimizes the expected energy cost for E2E traversal of a packet between the two nodes in a multihop network [4]. The energy cost of a path is analysed in four steps:

1. Analysing the expected transmission count of data and ACK packets.
2. Analysing the expected energy cost of a link taking into account the energy cost of retransmissions.
3. Analysing the E2E reliability of a path.
4. Formulating the energy cost of a path taking into account the energy cost of links and E2E reliability of the path.

This in-depth analysis of the energy cost lays the foundation for designing RMER and RMECR algorithms for the HBH system [3].

In the proposed a novel energy-aware routing algorithm, called reliable minimum energy cost routing (RMECR). RMECR finds energy efficient and reliable routes that increase the operational lifetime of the network. RMECR is proposed for networks with hop-by-hop (HBH) retransmissions providing link layer reliability, and networks with E2E retransmissions providing E2E reliability. It considers the energy consumption and the remaining battery energy of nodes as well as quality of links to find energy-efficient and reliable routes that increase the operational lifetime of the network[3].

Proposed Algorithm

1. Initially BS collects information regarding of all the nodes in the network.
2. Assigning energy to all nodes.
3. Choose the source and destination.
4. To find the neighbours.
5. Choose the shortest routing using Dijkstra's algorithm
6. Calculating the minimum energy routing path for using MinMax algorithm
7. Sending packets through the reliable path.

The basic steps for attaining the comparative analysis are given below.

A. Turn on Tracing Window

This window traces the simulation events at each and every seconds of the given simulation period.

B. Turn on Tracing Window

The next step is to give topology for the network. For the WANET, the specified topology is MESH. For any wireless network, it is necessary to give all the necessary parameters like type of channel, type of ad-hoc routing protocol, type of antenna, etc.

C. Turn on Tracing Window

This section will create the appropriate routing agents for the data flow. In WANET, TCP has been used. It is much more reliable than the other and it is the one which has been supported easily by NS-2. It provides the routing algorithm for the network.
D. Turn on Tracing Window

The script might create some output on stdout, it might write a trace file or it might start name to visualize the simulation. It is a discrete event simulator and very much useful for analysis of dynamic nature of communication network. [4]. The pictorial representation of algorithm shown in Fig.1

![Fig.1 Pictorial representation of Algorithm](image)

In Fig.1, first the nodes are created and energy is assigned to those nodes. During this process, HELLO packet are send to the neighbouring nodes and this process continues until all the nodes in the network receives the HELLO packet. In the second step, find the source and destinations nodes. As the next step, find all the shortest path between the source and destination and select the path that consumes minimum energy for transferring the data. This path is considered as the reliable path.

V. SIMULATION RESULT

We carry out simulation in ns2 for evaluating the proposed routing protocol. Packet delivery ratio, Throughput, Average energy consumption is compared. The simulation program has been written in C++. The main simulation parameters are shown in Table 2. To evaluate the performance of RMECR and RMER algorithms, we consider a network in which nodes are uniformly distributed in a square area. Nodes are assumed to be static [3].

TABLE I
VALUES OF VARIOUS PARAMETERS USED IN SIMULATIONS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial battery energy of each node (B)</td>
<td>100[J]</td>
</tr>
<tr>
<td>Network area</td>
<td>350 x 350 [m²]</td>
</tr>
<tr>
<td>Path-loss exponent (η)</td>
<td>3</td>
</tr>
<tr>
<td>Data rate(γ)</td>
<td>100[Kbps]</td>
</tr>
<tr>
<td>Power consumption of transmitter circuit (Pt)</td>
<td>100 [mW]</td>
</tr>
<tr>
<td>Power consumption of receiver circuit (Pr)</td>
<td>100 [mW]</td>
</tr>
<tr>
<td>Maximum transmission power(Pmax)</td>
<td>150 [mW]</td>
</tr>
<tr>
<td>Minimum transmission power(Pmin)</td>
<td>15 [mW]</td>
</tr>
<tr>
<td>Power efficiency of transmission amplifier (k)</td>
<td>10%</td>
</tr>
<tr>
<td>Maximum # of transmissions in HBH system (Qu)</td>
<td>7</td>
</tr>
<tr>
<td>Transmission range (dmax)</td>
<td>70 [m]</td>
</tr>
<tr>
<td>Data packet size (Ld)</td>
<td>512 [byte]</td>
</tr>
<tr>
<td>MAC ACK packet size (Ld)</td>
<td>240 [bit]</td>
</tr>
<tr>
<td>E2E ACK packet size (Lc)</td>
<td>96 [byte]</td>
</tr>
<tr>
<td>Hello packet size (Lhello)</td>
<td>96 [byte]</td>
</tr>
<tr>
<td>Battery death threshold (Bth)</td>
<td>0</td>
</tr>
<tr>
<td>Maximum collision probability (pcmax)</td>
<td>0.3</td>
</tr>
<tr>
<td>Channel sensing time (T sense)</td>
<td>50 [µs]</td>
</tr>
<tr>
<td>k idle</td>
<td>0.2</td>
</tr>
<tr>
<td>k sense</td>
<td>0.4</td>
</tr>
<tr>
<td>Thello</td>
<td>10 [s]</td>
</tr>
<tr>
<td>T tc</td>
<td>20 [s]</td>
</tr>
</tbody>
</table>

Simulation is carried out several times and averages of the results obtained are used for plotting the graphs showing the trends.

![Fig.2 Packet delivery ratio for RMER protocol](image)
VI. CONCLUSION

Energy-aware routing in ad hoc networks is done, and proposed a new routing algorithm for wireless ad hoc networks, namely, reliable minimum energy routing (RMER). RMER can increase the operational lifetime of the network using energy-efficient and reliable routes. In the design of RMER, a detailed energy consumption model is used for packet transfer in wireless ad hoc networks. RMER was designed for two types of networks: those in which hop-by-hop retransmissions ensure reliability and those in which end-to-end retransmissions ensure reliability. RMER finds routes minimizing the energy consumed for packet traversal. RMER does not consider the remaining battery energy of nodes, and was used as a benchmark to study the energy-efficiency of the RMECR algorithm. Extensive simulations showed that RMER not only saves more energy compared to existing energy-efficient routing algorithms, but also increases the reliability of wireless ad hoc networks. Furthermore, it is observed that RMER finds routes that their energy-efficiency and reliability high paths.

REFERENCES