Hardware Implementation of Energy Efficient Routing Protocol for Mobile Ad Hoc Networks

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May 23, 2018

Abstract

MANET (Mobile ad-hoc network) is an infrastructure less and self-organized wireless communication network with compact battery operated nodes which can act as a host as well as a router. They can sense, process and communicate wirelessly. As the nodes in MANET are mobile they can enter or leave the network at any time. This may lead to partitioning of the network causing rediscovery of routes between source and destination. Due to this there is increase in the energy consumption of nodes leading to their premature dying and partitioning the network which further results into decrease in the network lifetime. Hence, MANETs require special routing protocols to reduce energy consumption of the nodes. The conventional routing protocols work on shortest path algorithm which selects the path that has minimum number of hops between source and
destination. But this may cause a few of the nodes to be used more than the others exhausting them early. Hence it is necessary to consider the energy of the nodes along with the hop count while selecting a route between source and destination. This paper considers the Dynamic Source Routing (DSR), a conventional on demand routing protocol and modifies it to enhance the energy efficiency of the nodes and the lifetime of network. An additional field which carries the residual battery capacity of the nodes on the route towards the destination is introduced in the modified algorithm. This modified protocol is named as Least Max DSR protocol (LMDSR). Physical deployment of the network can help to test different real life conditions without any prior assumptions to accurately prove if the proposed design and algorithm are performing as per expectations or not. Hence the performance comparison of DSR and LMDSR protocols is done with the help of hardware implementation using microcontroller Atmega328 and ZigBee. Six hardware nodes were used during experimentation to calculate the network lifetime and end to end delay. It was observed that the LMDSR algorithm has 13% more network lifetime than that of DSR and end to end delay is reduced by 1.2%.

**Key Words:** Energy efficiency; energy consumption; residual battery capacity; network lifetime; end to end delay.

1 Introduction

Lack of centralized administration, energy constraint nodes, and dynamic network topology are some of the main challenges in MANETs. The network may get partitioned as the mobile nodes can move out of the network or range at any time. This makes it necessary for the nodes to use multi hop communication as the nodes have limited transmission range. A node can act as a host and a router. A router is responsible for routing process. Routing is a process of choosing path between a source and a destination to communicate data over it. The nodes present in the network can initiate a fresh route discovery process to re-establish the brokenlink due to any sudden change in topology. The conventional routing protocols work on shortest path algorithm which selects the path that has minimum number of hops between source and destination causing a few of
the nodes to be used more than the others and exhaust them early. Hence it is necessary to consider the energy of the nodes along with the hop count while selecting a route between source and destination. Hence MANET requires special routing protocols which can take care of the typical restraints like small bandwidth, large error rates and importantly the limited battery power. The MANET routing protocols are classified into three broad categories namely, proactive, reactive and hybrid. In proactive routing [1], every node continuously updates the information of the routes to the other nodes in the network in a table. But this may result into wastage of power and bandwidth. Also if there is increase in the number of nodes in the network then the table size will also increase. Unlike proactive protocols, reactive protocols [2] initiate the route discovery process as and when a source or transmitter node desires to communicate with destination or receiver node. There is no frequent updating of the route tables with change in network topology. This results in saving of power and bandwidth. AODV and DSR [3] are some of the examples of reactive protocol. Nodes in MANETs have scarcity of bandwidth as well as battery and hence they impose a severe constraint on routing process. Route discovery process enforces substantial control overheads and power consumption. Conventional on-demand routing protocols select a shortest path and are not energy aware making the nodes die prematurely. Due to this partitioning of the network may take place leading to re-discovery of the route. This will negatively affect the lifetime of the nodes as well as the whole network. Therefore considering the residual battery capacity of the nodes to balance the load during the routing process can enhance the energy efficiency of the nodes which will further lead to extend the overall network lifetime. This paper proposes modification to existing on demand routing protocol to extend the network lifetime and its hardware implementation.

2 LITERATURE REVIEW

A. Existing algorithms to enhance energy efficiency

Authors in [4] have presented the performance analysis of DSR, AODV, OLSR and DSDV protocols using simulator NS2. Here
three parameters viz. network area, number of nodes, and pause
time are considered for simulation in order to study effect of variation of one of these parameters on the packet delivery ratio (PDR) while keeping other parameters constant. From the simulation results it was seen that the DSR protocol outperforms in terms of average PDR for high mobility of nodes as compared to DSDV, OLSR and AODV protocols.

Paper [5] suggests a new routing protocol called Energy-balanced Dynamic Source Routing (EB-DSR). In EB-DSR, the source route request header has an additional field for energy of the nodes on the route to exchange the information of their residual energies. To avoid premature exhaustion, the low-energy nodes which may cause partitioning of the network or communication link breakage are not selected during route discovery process. But the authors have considered static and fixed number of nodes for simulation. Thus the effect of increase in number of nodes and their mobility on network lifetime has not been discussed.

A new algorithm is proposed in [6] which considers two metrics namely, residual battery of the nodes and their relay-capacity. Here a trade-off of balancing the load while minimizing the energy consumption is suggested in order to increase the network lifetime. The proposed algorithm uses neighbouring node table, group table and routing table to forward data packets from one node to another. Average 20% improvement is observed in network lifetime from the simulation results.

Authors in [7] present an approach called as Maximal Power Conserved and Battery Life Aware Routing (MPC-BLAR). Here every node in the network creates and retains a table to store the existing battery level of its immediate hop level nodes and the status of RREQ. Authors have proposed a new process that makes the nodes to interchange their existing battery levels with their neighbour nodes and this process is repeated periodically.

Authors in [8] have proposed Efficient Power Aware Routing (EPAR) to improve the lifetime of MANET. EPAR detects the ability of a node by considering two factors: 1) its outstanding battery power and 2) the probable energy consumed in forwarding data reliably over selected path. EPAR selects the path that requires smallest residual energy for transmitting the largest packets. The simulation results show that total energy consumption is re-
duced by more than 20% at the same time attaining a good PDR. Also there is decrease in the mean delay, specifically for large load networks. When the network nodes exceed 60 in number then the throughput of EPAR rises rapidly than that of MTPR and DSR.

Energy Efficient Delay Time Routing (EEDTR) and Maximized Energy Efficient Routing (MEER) algorithms are proposed in [9] to increase the working lifetime of MANETs. These two algorithms are based on the conventional DSR algorithm. The MEER algorithm takes the remaining energy of the nodes on the path into account to choose the best route. The EEDTR algorithm makes use of a variable delay in forwarding the route request packets. Simulation results indicate that the control overhead of modified protocols is lesser than that of DSR. Also the average energy left is more with modified protocols demonstrating increased node lifetime.

Authors in [10] have proposed two energy-aware algorithms called as reliable minimum energy cost routing (RMECR) and reliable minimum energy routing (RMER). These algorithms consider the residual battery of nodes as well as the energy consumption and links quality to find reliable and energy-efficient routes. RMER focuses on finding a route that minimizes the total energy that is essential for communication of packet from source to destination. Simulation evaluation shows that RMER increases the reliability of networks at the same time saving more energy in comparison with other energy efficient routing algorithms. RMECR selects the route that has nodes with more residual energy to extend the network lifetime.

From the literature review it has been observed that a lot of simulation work is done by the researchers all over the world to improve the energy efficiency of the MANETs. But there is very less work done on the physical deployment of the MANETs to test different real life conditions to accurately prove if the proposed design and algorithm are performing as per expectations or not. This paper tries to test the hardware implementation of energy efficient routing algorithm.

**B. Hardware platforms, their Features and Functionalities**

Different types of wireless sensor/ad hoc network platforms are available due to diversity in wireless networking issues and applications. A hardware platform must be capable of serving the needs of an application such as access and testing under realistic condi-
tions and constraints. The nodes in a MANET have inadequate resources such as transmission range, computational power, bandwidth and, battery capacity. Also they make use of highly effective communication protocols [11].

The hardware platforms basically consists of a microcontroller/microprocessor, sensor/s module, radio transceiver, power source and memory. For radio module, IEEE 802.15.4 standard has been focused and study of various hardware platforms like Arduino MEGA 2560, Libelium WaspMote, SENSeNuts WSN Platform, TelosB mote and Micaz mote has been done to compare their functionalities and features.

Understanding IEEE 802.15.4 and ZigBee

IEEE 802.15.4 standard is popularly used protocol for communication in wireless sensor/ad hoc networks. IEEE 802.15.4 standard specifies the PHYsical (PHY) and Medium Access Control (MAC) layers for low-rate Wireless Personal Area Networks (WPAN) with pervasive connectivity between low-power and low-cost fixed or mobile nodes [12]. It lies over the data link layer which is the second layer of Open System Interconnection (OSI) model. This layer organizes the digital information bits and converts into electromagnetic waves. It has two addressing modes viz. 16-bit short and 64-bit IEEE addressing and provides maximum data rate of 250 kbps [13]. The 802.15.4 uses Guarantee Time Slots (GTS) and Carrier Sense Multiple Access-Collision Avoidance (CSMA-CA) to avoid collisions due to simultaneous broadcasting of information by all the nodes. In CSMA-CA each node checks if the energy of medium is found to be higher than a specific level then the node has to try again after waiting for certain random time interval. GTS requires a central coordinator known as PAN coordinator to allocate time slots to each node. A node must send a GTS request to PAN coordinator. The PAN coordinator responds by replying with a beacon message that contains the allocated slot and the number of slots assigned to the requesting nodes. The 802.15.4 performs the channel energy scan to check if the channel energy is higher or if the medium is already occupied. A node will be allowed to transmit only when the channel energy is lesser than a threshold or the medium is free. IEEE 802.15.4 is used as MAC layer by several protocols. The most widely used protocol is ZigBee which offers four services viz. extra encryption services, association and authentication, routing protocol and application [14]. ZigBee
network has three categories of nodes, namely router, coordinator and end device. The end devices can establish connection with a coordinator or a router. The routers are able to connect with each other as well as with the coordinator.

From the detailed survey of various hardware platforms it was observed that almost all of them use microcontroller operating at 8 or 16 MHz frequency with radio module using IEEE 802.15.4/ZigBee as wireless communication protocol. The Libelium Wasp mote [14] has built-in temperature and accelerometer sensors on the board while the Sensenuts CustomLab [15] can extend its radio module by connecting a sensor module. For Arduino board [16], the sensors need to be interfaced externally. The TelosB [17] and Micaz motes [18] have a facility to optional plug and play with MEMSICs sensor boards, data acquisition boards, and gateways. The software programming language for all these platforms is similar to C/C++. The comparison of features of these platforms will help the designers to select appropriate board for their applications. Table III gives the comparison of the hardware platforms.

3 PROPOSED ALGORITHM AND HARDWARE IMPLEMENTATION

A. Proposed Algorithm

Conventional DSR protocol is modified to extend the network lifetime by adding an extra field in the route request packet to update the residual battery capacity of the nodes on the paths between the source and the destination. The algorithm is as given below:

1. Start

2. Source node broadcasts the route request (RREQ) packet to its neighbouring nodes.

3. Destination node caches all the routes from which it receives RREQ packets and compares the residual battery capacities of the nodes on the cached routes.

4. Destination node selects the route which has the node with highest remaining battery capacity among all the nodes with least remaining battery capacity on these routes. This ensures selection of a route that has all the nodes with larger remaining battery
capacity as compared to the other routes between same source and destination pair.
5. Route reply (RREP) will be sent back to source node over the same route with higher energy nodes.
6. Stop.

B. Hardware implementation using arduino microcontroller AT-mega328 and ZigBee

Fig. 1 shows the block diagram of a single node. Such six nodes are built one source, one destination and 4 intermediate nodes.

Fig. 1 Block diagram of wireless sensor node

Following components were used to build a single node in MANET:
1. ATmega328 - Arduino microcontroller
2. ZigBee radio transceiver
3. LM 35 as temperature sensor

Fig. 2 shows the routing process in conventional shortest path algorithm and that of the proposed energy efficient path.

Fig. 2 Placement of nodes and routing paths

4 EXPERIMENTAL RESULTS

1. End to End Delay (Sec.) of DSR and LMDSR

From the result Table II it is seen that end to end delay in DSR mode is 1.2% higher than Energy saving mode.
2. Network lifetime:

For the measurement of network life time the communication is continued in DSR and LMDSR modes till all the nodes are drained out or communication between source and destination is stopped.

From the results in Table III it is seen that all the nodes in DSR mode were drained after 1.15 hrs. while the all the nodes in LMDSR mode were drained after 1.30 hrs. This shows that the network lifetime in LMDSR mode is 13% higher than DSR mode.

5 CONCLUSION

This paper has discussed detailed review of energy efficient algorithms and hardware platforms for real world implementation of MANET. It also elaborates the role and significance of IEEE 802.15.4 and ZigBee in hardware implementation of MANET. From the experimental results it is observed the proposed modified algorithm called as Least Max DSR (LMDSR) ensures that the selected route has nodes with highest residual battery capacity among all the nodes with least remaining battery capacity on these routes. This guarantees selection of a route that has all the nodes with larger remaining battery capacity as compared to the other routes between same source and destination pair. Further hardware implementation of MANET is done to compare the conventional DSR.
algorithm with modified energy efficient LMDSR algorithm. Experimental results of the hardware implementation show that the end to end delay in DSR mode is 1.2% higher than LMDSR mode while the network lifetime in LMDSR mode is 13% higher than DSR mode.

TABLE III. TABLE OF COMPARISON OF HARDWARE PLATFORMS

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<tr>
<th>Parameter</th>
<th>Atheros 150NH</th>
<th>Atheros 150UB</th>
<th>Atheros 300NH</th>
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<td>$365</td>
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<td>802.11a/b/g/n</td>
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<tr>
<td>Current</td>
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<td>240 mA</td>
<td>240 mA</td>
<td>240 mA</td>
</tr>
</tbody>
</table>

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