Survey of Various Energy Efficient Multicast Routing Protocols for MANET

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Abstract

This paper presents a thorough survey of current work addressing energy efficient multicast routing protocols in Mobile Ad hoc Networks (MANETs). There are so many different issues and solutions which witness the need of energy management in ad hoc wireless networks. The goal of a multicast routing protocol for MANETs is to support the propagation of data from a sender to all the receivers of a multicast group while trying to use the available bandwidth efficiently in the presence of frequent topology changes. Multicasting can improve the efficiency of the wireless link by sending multiple copies of messages by exploiting the inherent broadcast property of wireless transmission. However, offering energy efficient multicast routing is very difficult and challenging task. Now a day, various multicast routing protocols have been proposed for MANETs. All these protocols have distinguishing features and use different mechanisms.

Keywords: Mobile Ad hoc Network, Multicast Routing Protocol, shared tree, alternate node, routing zone, Energy Efficiency

1. Introduction

An ad hoc network consists of a collection of autonomous mobile nodes formed by means of multi-hop wireless communication without the use of any existing network infrastructure. Ad hoc networks have become increasingly relevant in recent years due to their potential applications in battlefield, emergency disaster relief and etc. In an ad hoc network, each mobile node can serve as a router. A mobile ad-hoc network (MANET) is characterized by mobile nodes without any infrastructure. Mobile nodes self-organize to form a network over radio links [20]. Group communication is important in Mobile Ad Hoc Networks (MANET). Many ad hoc Network applications which require close association of the member nodes depends on group communication. Disaster relief, conferences, action directions given to the soldiers in a battlefield and communications required during a rescue operation are some examples of these applications. In addition, many routing protocols for wireless MANETs need a broadcast/ multicast as a communication primitive to update their states and maintain the routes between nodes [1, 19].

Multicast protocols can be categorized in tree based and mesh based protocols. Multicast tree structures are fragile therefore need to be readjusted and repaired continuously as the connectivity changes. Even in wired networks maintaining group membership information and building an optimal multicast distribution structure (typically in the form of a routing tree) is challenging. A detailed survey of the work done in that area and a discussion of various design tradeoffs can be found in [2]. One particularly challenging environment is a mobile ad-hoc network (MANET). Nodes are free to move arbitrarily. Bandwidth scarcity, limited power resource, and above all dynamicity of topology in a mobile ad hoc network make the multicast protocol design predominantly challenging than that for wired network [19].

However, it would be a difficult and challenging task to offer energy efficient and reliable multicast routing in MANETs. It might not be possible to recharge / replace a mobile node that is powered by batteries during a mission. The inadequate battery lifetime imposes a limitation on the network performance. To take full advantage of the lifetime of nodes, traffic should be routed in a way that energy consumption is minimized. In recent years, various energy efficient multicast routing protocols have been proposed.
These protocols have unique attributes and utilize different recovery mechanisms on energy consumption. This paper will provide a comprehensive understanding of these multicast routing protocols and better organize existing ideas and work to make it easy to design multicast routing in MANETs. The goal of this paper is to help researchers to gain a better understanding of energy-efficient routing protocols available and assist them in the selection of the right protocol for their work. The rest of the paper is organized as follows: Section 2 presents related work on comparisons and surveys of multicast routing protocols for MANETs. Section 3 describes the energy-efficient multicast routing protocols and Section 4 concludes the paper.

2. Related Work

A number of multicast protocols have been proposed to provide multicasting in MANET like challenging environments [3, 4]. A multicast packet is delivered to all the receivers belong to a group along a network structure such as tree or mesh, which is constructed once a multicast group is formed. Based on this network structure, multicast protocols can be broadly categorized into two types, namely tree-based multicast and mesh-based multicast. A tree-based multicast routing protocol is either a source-tree or a shared-tree protocol. In a source tree based multicast routing protocol data packets are delivered through multiple source-based routing trees routed at the sources of the multicast session and in shared tree protocol data packets are delivered along a shared multicast tree for the whole multicast group. Shared tree protocols construct a single tree for a multicast group which is shared by all senders. If the nodes in the network are highly dynamic, a large number of source trees might need reconstruction, causing excessive overhead in case of source-tree multicast [5]. On the other hand, shared tree multicast is more scalable because of lower control overhead requirement for maintaining only a single shared tree for all multicast sources [6]. The shared tree approach has some other drawbacks. The paths are non-optimal and traffic is concentrated on the shared tree, rather than being evenly distributed across the network [19]. The shared tree based protocols need a group leader (or a core or a rendezvous point) to maintain group information and to create multicast trees. To deal with the problem of dynamic nature of MANET, mesh based protocols provide a number of redundant paths between a pair of sender and receiver. This in turn results in a great number of controls overhead [19].

Tree based protocols are generally more efficient in terms of data transmission, but they are not robust against topology changes as there is no alternative path between a source and a destination, while mesh-based protocols are more robust against topology changes due to availability of many redundant paths between mobile nodes, resulting in high packet delivery ratio. On the other hand, multicast mesh does not perform well in terms of energy efficiency because mesh-based protocols depend on broadcast flooding within the mesh and therefore, involving many more forwarding nodes than multicast trees. In summary, the broadcast forwarding in mesh based protocols produces redundant links, which improves the packet delivery ratio but spends more energy than the tree-based multicast [19].


MANETs lack fixed infrastructure and nodes are typically powered by batteries with a limited energy supply wherein each node stops functioning when battery drains. Energy efficiency is an most important consideration in such an environment. Since nodes in MANETs rely on limited battery power for their energy, energy-saving techniques aimed at minimizing the total power consumption of all nodes in multicast group (minimize the number of nodes used to establish multicast connectivity, minimize the control overhead and so on) and at maximizing the multicast life span should be considered. As a result of energy constraints placed on the network’s nodes, designing energy efficient multicast routing protocols is a crucial concern for MANETs, to maximize the lifetime of its nodes and thus of the network itself [7,8,20].

4. Energy Efficient Clustering Technique (EECT)

An energy efficient clustering technique (EECT) [9] is multicast routing protocol in which each node uses weight cost function based on the transmission power level, residual power and node speed to form cluster in the neighboring area and the node with the minimum weight value is selected as the cluster head. The EECT can alleviate the energy consumption because the communication between cluster head and member is adjustable with appropriate power level. The tree based MAODV and the mesh-based ODMRP ad hoc multicast routing protocols are adapted to the EECT being executed on the each cluster head. Simulation results demonstrate that adaptation of MAODV and ODMRP using EECT have better system performance than MAODV and ODMRP in terms of total energy consumption, mean end-to-end delay, and mean hop count, packet delivery ratio and percentage of alive nodes for different multicast group size and mobility.

5. Scalable Energy Efficient Location Aware Multicast Protocol (SEELAMP)

A scalable and energy efficient location aware multicast algorithm, called SEELAMP [25], for mobile ad hoc networks is based on creation of shared tree using the physical location of the nodes for the multicast sessions. It constructs a shared bi-directional multicast tree for its routing operations rather than a mesh, which helps in
achieving more efficient multicast delivery. Algorithm uses the concept of small overlapped zones around each node for proactive topology maintenance within the zone. Protocol depends on the location information obtained using a distributed location service, which effectively reduces the overheads for route searching and shared multicast tree maintenance. In this algorithm a new technique of local connectivity management is being proposed that attempts to improve the performance and reliability. It employs a preventive route reconfiguration to avoid the latency in case of link breakages and to prevent the network from splitting.

6. An Optimized and Energy Efficient Multicast Routing Based on Genetic Algorithm

Authors are focused on energy consumption efficiency which generally means selecting the node with the minimum energy consumption in the route selection. When this mechanism generates an improper phenomenon, some nodes with superior conditions are selected, resulting in rapid battery energy consumption. In this excessive usage situation, such schemes will further shorten the lifetime of the multicast tree and quickly end the multicast service. Authors adopted a strategy for balancing battery energy consumption in the entire multicast tree to prolong its maximum lifetime. Retaining an energy-efficient genetic algorithm, they improved the mating mechanism and introduced energy efficient mutation as the repair function. This method is applicable for reducing the node degree by replacing nodes with lower energy with nodes with higher energy. The total battery energy consumption for the multicast service is distributed using higher residual battery energy nodes [10].

7. Stable Energy-Efficient Position-Based Multicast Routing (SE³PBM)

In this routing algorithm, the problem of energy efficient multicasting in mobile ad hoc networks is tackled with incorporation of minimum required stability along each path. A novel model is presented to compute the stability of links as a function of transmission power of forwarding nodes and mobility history of links. Authors present a mixed integer programming model which can be used for an optimal solution of the minimum energy multicast routing with stable paths in mobile ad hoc networks. Further, they propose a source-initiated distributed heuristic position-based multicast routing algorithm (SE³PBM) [11] to construct minimum energy consumption multicast trees in mobile ad hoc networks. SE³PBM selects transmission power level of forwarding nodes in order to guarantee certain stability requirement, while minimizing total energy cost.

8. Energy Efficient Delay Time Routing Algorithm (EEDTR) and Maximised Energy Efficient Routing (MEER)

Author proposes two algorithms called Energy Efficient Delay Time Routing (EEDTR) and Maximised Energy Efficient Routing (MEER) [12], which try to increase the operational lifetime of Mobile Ad hoc networks. These algorithms are modified versions of the existing Dynamic Source Routing (DSR) algorithm. These algorithms select fully distributed routes, thus balancing power consumption of the entire network. The first algorithm (EEDTR) introduces a delay in forwarding the packets by nodes, which is inversely proportional to the remaining energy level of the node. The second algorithm includes energy information on the route request packet and selects the routes based on this information (MEER). These algorithms are designed and implemented using Global Mobile Simulator (GloMoSim), a scalable, simulation environment for network simulation. Based on the results obtained, Author concludes that the proposed algorithms increase the lifetime of mobile ad hoc networks, at the expense of end to end delay and control overhead. The Energy Efficient Delay Time Routing algorithm is based on the DSR protocol. The Route Discovery procedure in the DSR protocol is modified to enable the selection of the most energy efficient routes by the source nodes. The Route Maintenance procedure is essentially the same as in DSR protocol.

9. A Distributed Algorithm for Building Energy efficient Group-Shared Multicast Tree

The group-based multicast is widely applied in wireless ad hoc networks because it has lower storage status messages in the nodes and lesser cost of overhead in the shared tree. Reduction in energy consumption and extending network lifetime in multicasting are two important issues. A new distributed algorithm called B-REMIT [13, 26] is proposed for building an energy efficient shared tree in ad hoc network. This algorithm B-REMIT focuses on the metric TEC (Total Energy Consumption) while its refining is guided by the metric SL (System Lifetime) of shared tree. This nice integration seems to well balance the two metrics by improving SL of multicast trees efficiently with little sacrifice on TEC [13, 26].


Authors present Multicasting through Time Reservation using Adaptive Control for Energy efficiency (MC-TRACE) [14], an energy-efficient real-time data multicasting architecture for MANET. MC-TRACE is one of the cross-layer design, where the medium access control layer functionality and the network layer functionality are
performed by a single integrated layer. The basic design philosophy behind the multicast routing part of the architecture is to establish and maintain an active multicast tree surrounded by a passive mesh within MANET. Thus, the MC-TRACE multicast backbone is a condensed passive mesh woven around a highly pruned tree. Although tree-based and mesh-based multicasting techniques have been used separately in existing multicasting architectures, the novelty in this study is the integration and reengineering of the tree and mesh structures to make them highly energy efficient and robust for real-time data multicasting in MANET. Energy efficiency can be achieved by enabling the nodes to switch to sleep mode frequently and by eliminating most of the redundant data receptions. The performance of MC-TRACE through NS-2 simulations and compared it with ODMRP. Results show that MC-TRACE provides better energy efficiency while producing competitive QoS performance and bandwidth efficiency.

11. Signal and Energy Efficient Clustering (SEEC)

Signal and Energy Efficient Clustering (SEEC) [15] algorithm is based on signal strength and energy level of nodes in MANET to improve system performance. The algorithm focuses on cluster head formation and maintenance, and prevents death of cluster head by making another cluster node as the cluster head when power level falls below certain threshold value.

12. Two-Tree Multicast (TTM)

The proposed TTM [16] uses two trees, a primary and an alternative backup tree, to improve energy efficiency. TTM consumes less energy than the mesh-based multicast because it uses multi-destined unicast-based multicast trees. TTM results in improved energy balance and packet delivery ratio compared to the conventional shared tree multicast (STM) because it can switch to the alternative tree when the primary tree is overloaded or becomes invalid. Performance evaluation study shows that the proposed TTM saves energy consumption by a factor of 1.9–4.0 compared to the mesh-based multicast. In terms of combined performance metric, energy per delivered packet, TMM shows up to 80% and 40% improved performance than the mesh-based multicast and the conventional shared tree multicast, respectively.

13. S-REMiT: A Distributed Algorithm for Source-based Energy Efficient Multicasting

A distributed algorithm called S-REMiT [17] builds an energy-efficient multicast tree in a wireless ad hoc network (WANET). S-REMiT employs a more realistic energy consumption model for wireless communication, which takes into account the energy losses not only due to radio propagation but also the energy losses in the transceiver electronics. This enables S-REMiT to adapt a given multicast tree for a wide variety of wireless networks irrespective of whether they use long-range radios or short-range radios. Simulations show that it performs better than BIP/MIP algorithm which is a centralized source-based broadcast/multicast tree building centralized algorithm and Embedded Wireless Multicast Advantage (EWMA) algorithms.

14. Node Selection Based On Energy Consumption

The nodes in mobile ad hoc network are fitted with batteries with limited capacities. In order to achieve an optimum route connection by extending the network lifetime, the distance factor of the source-intermediate-destination needs to be combined with the initial energy of the node when selecting a participating node in a route path [18]. A probability based node selection method is proposed in this new algorithm for identifying the intermediate node with optimum stored energy that could withstand through duration of connection. This algorithm has been tested with simulations and it has been proved that the node with the largest probability consumes the lowest energy. This not only helps to sustain the communication with the lowest chance of interruption, but also prolongs the network lifetime because of the lowest possible consumption of energy for a given communication [18].

15. Power-aware Routing (PAR) Protocol

Power-aware routing (PAR) [21] maximizes the network lifetime and minimizes the power consumption by selecting less congested and more stable route, during the source to destination route establishment process, to transfer real-time and non-real-time traffic, hence providing energy efficient routes. PAR focuses on 3 parameters: Accumulated energy of a path, Status of battery lifetime and Type of data to be transferred. At the time route selection, PAR focuses on its core metrics like traffic level on the path, battery status of the path, and type of request from user side. With these factors in consideration, PAR always selects less congested and more stable routes for data delivery and can provide different routes for different type of data transfer and ultimately increases the network lifetime. Simulation results shows that PAR outperforms similar protocols such as DSR and AODV, with respects to different energy-related performance metrics even in high mobility scenarios. Although, PAR can somewhat incur increased latency during data transfer, it discover routed that can last for a long time and encounter significant power saving [20].

16. Localized Energy-aware Routing (LEAR) Protocol

Local Energy-Aware Routing (LEAR) [22] simultaneously optimizes trade-off between balanced
energy consumption and minimum routing delay and also avoids the blocking and route cache problems. LEAR accomplishes balanced energy consumption based only on local information, thus removes the blocking property. Based on the simplicity of LEAR, it can be easily be integrated into existing ad hoc routing algorithms without affecting other layers of communication protocols. Simulation results show that energy usage is better distributed with the LEAR algorithm as much as 35% better compared to the DSR algorithm. LEAR is the first protocol to explore balanced energy consumption in a pragmatic environment where routing algorithms, mobility and radio propagation models are all considered [20,23, 24].

17. Conclusions

A mobile ad hoc network (MANET) consists of groups of autonomous mobile nodes, each of which communicates directly with the nodes within its wireless range or indirectly with other nodes in a network. In order to facilitate reliable communication within a MANET, an efficient routing protocol is required to discover routes between mobile nodes. The area of MANET is rapidly growing because of the many advantages and various application areas. Energy efficiency, low control overhead, security, reliability are some challenges faced in MANETs, especially in designing a routing protocol. In this paper, we consider a number of energy efficient multicast routing protocols. In many cases, it is very difficult to compare these protocols with each other directly since each protocol has its own goal with different assumptions and employs mechanisms to achieve this goal. According to the survey, these protocols have their strengths and drawbacks. Any multicast protocol can hardly satisfy all requirements. In other words, one routing protocol cannot be a solution for all QoS related issues that are faced in MANETs, but rather each protocol is designed to provide the maximum possible requirements, according to certain required scenarios. In future years, as mobile computing keeps growing, MANETs will continue to flourish, and even if a multicast protocol meeting all requirements it is designed for, it will be very complicated and will need a tremendous amount of routing information to be maintained. Satisfying most of the requirements would provide support for low control overhead, secure and reliable communication, minimize storage and resource consumption, ensure optimal paths and minimize network load.

References


