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A REVIEW OF ENERGY EFFICIENT ROUTING PROTOCOLS FOR MOBILE AD-HOC NETWORK

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Abstract: This paper presents a thorough survey of recent work addressing energy efficient routing protocols in Mobile Ad hoc Networks (MANETs). There are so many issues and solutions which witness the need of energy management in ad hoc wireless networks. The objective of a routing protocol for MANETs is to support the propagation of data from a sender to all the receivers while trying to use the available bandwidth efficiently in the presence of frequent topology changes. However, offering energy efficient routing is a difficult and challenging task. In recent years, various routing protocols have been proposed for MANETs. These protocols have distinguishing features and use different mechanisms.

Keywords: Mobile Ad hoc Networks, Routing Protocols, Energy Efficiency, Review Survey

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. The goal of MANETs is to broaden mobility into the area of autonomous, mobile and wireless domains, where a set of nodes form the network routing infrastructure in an ad-hoc manner. This emerging trend has stirred the support of applications which range from highly dynamic Vehicular ad hoc networks (VANETs) to less dynamic applications such as moderately mobile peer-to-peer wireless networks.

In ad hoc networks, nodes communicate with each other by way of radio signals, which are broadcast in nature. Broadcast is a unique case of multicast, wherein all nodes in the network should get the broadcast message. Multicasting is a communication process in which the transmission of packets (message) is initiated by a single user and the message is received by one or more end users of the network. Multicasting in wired and wireless networks has been advantageous and used as a vital technology in many applications such as audio/ video conferencing, corporate communications, collaborative and groupware applications, distance learning, stock quotes, distribution of software, news and etc [1].

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 routing protocols have been proposed. These protocols have unique attributes and utilize different recovery mechanisms on energy consumption. This project will provide a comprehensive understanding of these routing protocols and better organize existing ideas and work to make it easy to design 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.

SURVEY OF ENERGY EFFICIENT ROUTING PROTOCOLS

MANETs lack fixed infrastructure and nodes are typically powered by batteries with a limited energy supply wherein each node stops functioning when the battery drains. Energy efficiency is an 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 the group (minimize the number of nodes used to establish connectivity, minimize the control overhead and so on) and at maximizing the life span should be considered. As a result of the energy constraints placed on the network's nodes, designing energy efficient routing protocols is a crucial concern for MANETs, to maximize the lifetime of its nodes and thus of the network itself [11], [12].

Energy-efficient broadcast routing algorithms called Minimum Longest Edge (MLE) and Minimum Weight Incremental Arborescence (MWIA) are introduced in [3][8]. MLE is able to achieve a longer network lifetime by reducing the maximum transmission power of nodes. With MLE, the likelihood that a node is overused is reduced significantly. This scheme was expanded by considering a scenario where we introduce edge weights on the basis of the remaining energy of the sending nodes and receiving nodes. MWIA was derived from this idea, which is the best possible solution for broadcast routing with the minimum largest edge-weight.

Cheng et al. proposed the Minimum Incremental Power (MIP) algorithm and it is known as the most energy-efficient heuristic in terms of the total energy consumption among all the topologies [6]. MIP is developed based on the Broadcast Incremental Power (BIP) algorithm. The MIP algorithm is used as a comparison for the solution to the Energy-balanced topology control problem, which instead of minimizing the total energy, minimizes the maximum energy consumption at each node.

Energy-Efficient Location Aided Routing (EELAR):

Energy Efficient Location Aided Routing (EELAR) Protocol [2] was developed on the basis of the Location Aided Routing (LAR) [13]. EELAR makes significant reduction in the energy consumption of the mobile node batteries by limiting the area of discovering a new route to a smaller zone. Thus, control packet overhead is significantly reduced. In EELAR, a reference wireless base station is used and the network's circular area centered at the base station is divided into six equal sub-areas. During route discovery, instead of flooding control packets to the whole network area, they are flooded to only the sub-area of the destination mobile node. The base station stores locations of the mobile nodes in a position table. Simulations results using NS-2 [14][15] showed that EELAR protocol makes an improvement in control packet overhead and delivery ratio compared to AODV [16], LAR [17], and DSR [18][19] protocols.

Online Max-Min Routing Protocol (OMM):

Li et al proposed the Online Max-Min (OMM) power-aware routing protocol [9] for wireless ad-hoc networks dispersed over large geographical areas to support applications where the message sequence is not known. This protocol optimizes the lifetime of the network as well as the lifetime of individual nodes by maximizing the minimal residual power, which helps to prevent the occurrence of overloaded nodes. In most applications that involve MANETs, power management is a real issue and can be done at two complementary levels (1) during communication and (2) during idle time. The OMM protocol maximizes the lifetime of the network without knowing the data generation rate in advance. The metrics developed showed that OMM had a good empirical competitive ratio to the optimal online algorithm [9] that knows the message sequence and the max-min achieves over 80% of the optimal node lifetime (where the sender knows all the messages ahead of time) for most instances and over 90% of the optimal node lifetime for many problem instances [3].

Power-aware Localized Routing (PLR):

The Power-aware Localized Routing (PLR) protocol [20] is a localized, fully distributed energy-aware routing algorithm but it assumes that a source node has the location information of its neighbors and the destination. PLR is equivalent to knowing the link costs from the source node to its neighbors, all the way to the destination. Based on this information, the source cannot find the optimal path but selects the next hop through which the overall transmission power to the destination is minimized [3].

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.

Minimum Energy Routing (MER) Protocol:

Minimum Energy Routing (MER) can be described as the routing of a data-packet on a route that consumes the minimum amount of energy to get the packet to the destination which requires the knowledge of the cost of a link in terms of the energy expanded to successfully transfer and receive data packet over the link, the energy to discover routes and the energy lost to maintain routes [10]. MER incurs higher routing overhead, but lower total energy and can bring down the energy consumed of the simulated network within range of the theoretical minimum the case of static and low mobility networks. However as the mobility increases, the minimum energy routing protocol's performance degrades although it still yields impressive reductions in energy as compared performance of minimum hop routing protocol [22].

Lifetime-aware Tree (LMT) Protocol:

The Lifetime-aware tree routing algorithm [18] maximizes the ad hoc network lifetime by finding routes that minimize the variance of the remaining energies of the nodes in the network. LMT maximizes the lifetime of a source based tree, assuming that the energy required to transmit a packet is directly proportional to the forwarding distance. Hence, LMT is said to be biased towards the bottleneck node. Extensive simulation results were provided to evaluate the performance of LMT with respect to a number of different metrics (i.e., two definitions of the network lifetime, the root mean square value of remaining energy, the packet delivery ratio, and the energy consumption per transmitted packet) in comparison to a variety of existing routing algorithms and Least-cost Path Tree (LPT) [23]. These results clearly demonstrate the effectiveness of LMT over a wide range of simulated scenarios.

Lifetime-aware Refining Energy Efficiency of Trees (L-REMIT):

Lifetime of a tree in terms of energy is the duration of the existence of the service until a node dies due its lack of energy. L-REMIT [4] is a distributed protocol and is part of a group of protocols called REMIT (Refining Energy efficiency of Trees). It uses a minimum-weight spanning tree (MST) as the initial tree and improves its lifetime by switching children of a bottleneck node to another node in the tree. A tree is obtained from the "refined" MST (after all possible refinements have been done) by pruning the tree to reach only group nodes. L-REMiT is a distributed algorithm in the sense that each node gets only a local view of the tree and each node can independently switch its parent as long as the tree remains connected that utilizes an energy consumption model for wireless communication. L-REMiT takes into account the energy losses due to radio transmission as well as transceiver electronics. L-REMiT adapts a given tree to a wide range of wireless networks irrespective of whether they use long-range radios or short-range radios [1], [4].

Localized Energy-aware Routing (LEAR) Protocol:

Local Energy-Aware Routing (LEAR) [24] 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 [3], [4].

Conditional Max-Min Battery Capacity Routing (CMMBCR) Protocol:

The Conditional Max-Min battery capacity routing (CMMBCR) [25] protocol utilizes the idea of a threshold to maximize the lifetime of each node and to fairly use the battery fairly. If all nodes in some possible routes between a source-destination pair have larger remaining battery energy than the threshold, the min-power route among those routes is chosen [3]. If all possible routes have nodes with lower battery capacity than the threshold, the max-min route is chosen. CMMBCR protocol selects the shortest path if all nodes in all possible routes have adequate battery capacity (i.e. the greater threshold). When the battery capacity for some nodes goes below a predefined threshold, routes going through these nodes will be avoided, and therefore the time until the first node failure, due to the exhaustion of battery capacity is extended. By adjusting the value of the threshold, we can maximize either the time when the first node powers down or the lifetime of most nodes in the network.

SPAN: An Energy Efficient Coordination Algorithm for Topology Maintenance:

SPAN: An energy-efficient coordination algorithm for topology maintenance [26] is a distributed synchronization technique for multi hop ad hoc wireless networks that minimizes energy consumption without notably diminishing the connectivity of the network. SPAN coordinates the "stay-awake and sleep" cycle of the nodes and also performs multi-hop packet routing within the ad hoc network, while other nodes remain in power saving mode and periodically check if they should remain awaken and become a coordinator. SPAN adaptively elects coordinators by allowing each node to use a random back-off delay to decide whether to become a coordinator in the network and rotates them in time. The back-off delay for a node is a function of the number of other nodes in the neighborhood and the amount of energy left in these nodes. This technique not only preserves network connectivity, it also preserves capacity, decreases latency and provides significant energy savings. The amount of energy saving provided by SPAN increases only slightly as density decreases. Current implementation of span uses the power saving features, since the nodes practically wake up and listen for traffic advertisements [3].

Power-aware Multiple Access (PAMAS) Protocol:

PAMAS [27] is an extension to the AODV protocol; it uses a new routing cost model to discourage the use of nodes running low on battery power. PAMAS also saves energy by turning off radios when the nodes are not in use. Results show that the lifetime of the network is improved significantly. There is a trivial negative effect on packet delivery fraction and delay, except at high traffic scenarios, where both actually improve due to reduced congestion. Routing load, however, is consistently high, more at low traffic scenarios. For the most part, PAMAS demonstrates significant benefits at high traffic and not-so-high mobility scenarios. Although, it was implemented on the AODV protocol, the technique used is very standard and can be used with any on-demand protocol. The energy-aware protocol works only in the routing layer and exploits only routing-specific information [5].

Geographic Adaptive Fidelity (GAF) Protocol:

Geographical adaptive fidelity (GAF) protocol [34], [42] reduces energy consumption in ad hoc wireless networks; it is used for extending the lifetime of self-configuring systems by exploiting redundancy to conserve energy while maintaining application fidelity. By identifying nodes that are equivalent from a routing perspective and then turning off unnecessary nodes, maintaining a constant level of routing fidelity, this protocol is able to conserve energy. GAF also uses application-and system-level information; nodes that source or sink data remain on and intermediate nodes monitor and balance energy use. GAF is independent of the underlying ad hoc routing protocol; simulation studies of GAF show that it can consume 40% to 60% less energy than other ad hoc routing protocol. Also, network lifetime increases proportionally to node density [3].

Prototype Embedded Network (PEN) Protocol:

The Prototype Embedded Network (PEN) protocol [11] exploits the low duty cycle of communication activities and powers down the radio device when it is idle. Nodes interact asynchronously without master nodes and thus, the costly master selection procedure as well as the master overloading problem can be avoided. But in order for nodes to communicate without a central coordinator, each node has to periodically wake up, make its presence by broadcasting beacons, and listens a moment for any communication request before powering down again. A transmitting source node waits until it hears a beacon signal from the intended receiver or server node. Then, it informs its intention of communication during the listening period of the server and starts the communication. Due to its asynchronous operation, the PEN protocol minimizes the amount of active time and thus saves substantial energy. However, the PEN protocol is effective only when the rate of interaction is fairly low, thus more suited for applications involving simple command traffic rather than large data traffic [3].

Protocol for Unified through Announcements (PUMA):

PUMA [5] is a protocol that uses simple announcements to elect a core for the group and inform all routers of their distance and next-hops to the core, join, and leave the group. PUMA provides the lowest and a very tight bound for the control overhead compared to ODMRP and MAODV. In other words, the control overhead of PUMA is almost constant node when mobility, number of senders, group size or traffic load is changed. It also provides the highest packet delivery ratio for all scenarios [3]. The mesh constructed by PUMA provides redundancy to the region containing receivers, thus reducing unnecessary transmissions of data packets. PUMA does not depend on the existence of any specific pre-assigned unicast protocol [1].

Predictive Energy-efficient Algorithm (PEMA):

The Predictive Energy-efficient Algorithm (PEMA) [29] exploits statistical properties of the network to solve scalability and overhead issues caused by large scale MANETs as opposed to relying on route details or network topology. The running time of PEMA depends on the group size, not network size; this makes PEMA fast enough even for MANETs consisting of 1000 or more nodes. Simulation results show that PEMA not only results in significant energy savings compared to other existing algorithms, but also attains good packet delivery ratio in mobile environments. A distinct feature in PEMA is its speed; it is extremely fast because its running time is independent of its network size and the routing decision does not rely on the information about network topology or route details [21].

CONCLUSIONS

A mobile ad hoc network (MANET) consists 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 secure and reliable communication within a MANET, an efficient routing protocol is required to discover routes between mobile nodes. The field of MNAETs is rapidly growing due to the many advantages and different application areas. Energy efficiency and security are some challenges faced in MANETs, especially in designing a routing protocol. In this paper, we surveyed a number of energy efficient routing protocols and secure routing protocols. In many cases, it is difficult to compare these protocols with each other directly since each protocol has a different goal with different assumptions and employs mechanisms to achieve the goal. According to the study, these protocols have different strengths and drawbacks. A protocol can hardly satisfy all requirements. In other words, one routing protocol cannot be a solution for all energy efficient and security 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 Location Aided Routing can be modified to provide support for secure communication, minimize storage and resource consumption, ensure optimal paths and minimize network load.

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