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Topology control in the mobile ad hoc networks in order to intensify energy conservation

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A B S T R A C T

Although studied for years, due to their dynamic nature, research in the field of mobile ad hoc networks (MANETs) has remained a vast area of interest. Since once distributed, there will be less to no plausibility of recharge, energy conservation has become one of the pressing concerns regarding this particular type of network. In fact, one of the main obligations of designers is to make efficient use of these scarce resources. There has been tremendous work done in different layers of protocol stack in order to intensify energy conservation. To date, numerous topology control algorithms have been proposed, however, only a few have used meta-heuristics such as genetic algorithms, neural networks and/or learning automata to overcome this issue. On the other hand, since nodes are mobile and thus in a different spatial position, as time varies, we can expect that by regulating time intervals between topology controls, one may prolong the network's lifetime. The main initiative of this paper is to intensify energy conservation in a mobile ad hoc network by using weighted and learning automata based algorithms. The learning automata, regulates time intervals between which the topology controls are done. The represented learning automata based algorithm uses its learning ability to find appropriate time-intervals so that the nodes would regulate the energy needed in order to exchange the information to their neighbors, accordingly. Moreover, at first we have represented two weighted based algorithms which extend two prominent protocols, namely *K*-Neigh and LMST. Then these algorithms are combined with a learning based algorithm which regulates time intervals between which the topology controls are done. In comparison with approaches that are based on periodic topology controls, proposed approach shows enhanced results. On the other hand, considering the learning ability of the learning automata based algorithms, composition of the aforementioned algorithms has been proven to be enhanced, in the respect of energy consumed per data transmitted, over those compared with.

1. Introduction

Progresses in the field of infrastructure-less communications in MANETs (Mobile Ad Hoc NETworks) and concomitant interest to solve remaining issues in these types of networks have led to numerous advances in this area. However, a few concerns still remain, one of which is the scarce energy resource in the MANETs. A very tangible scenario in which a MANET is used, is when nodes are distributed in the field due to an emergency occurrence such as an earthquake, henceforth, there will be less to no plausibility of recharge. Depletion of one node's battery might lead to the rupture of the network's communication graph and thus lead to the end of the network's lifetime. Topology Control (TC) is simply defined as maximizing/

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minimizing certain properties in order to enhance the network's overall condition, whilst maintaining its connectivity. Topology controls can be done periodically. However, nodes are mobile and thus in a different spatial position, as time varies, a substantial amount of energy will be spent in the time-intervals between topology controls. We can expect that by regulating time-intervals between topology controls, one may prolong the network's lifetime. In this paper, we will use a learning automata based algorithm to regulate hello-intervals. Due to the importance of energy consciousness in the MANETs, we will focus on topology control approaches to decrease consumed energy per transmitted data. This paper is organized as follows:

In the second section a brief review of some of the previously done works on the TC has been given. Consequently, in section three we will briefly discuss the learning automata used in this concept. Later, in the section four, we will propose some topology control algorithms along with scheduling abilities followed by section five in which, we will show their performance using simulation results via OPNET simulator. The final section concludes the paper.

2. Related works

There have been tremendous works done in order to conserve energy in wireless networks. In [1], based on eligibility of the neighbor nodes, *K* nodes will be chosen as one node's neighbors. Eligibility is gained through metrics, among which fairness is considered. Nodes with higher capacity will be prioritized over nodes with less capacity. This knowledge over a node's energy reserve is gained through the first phase within which, each node will broadcast its capacity and identity. Second phase is done in order to make a symmetric graph. This protocol does not use nearest-neighbor as a sole criterion for routing and it is localized. In case of mobility topology control has to be done frequently.

Nevertheless, in some articles, mobility is not considered. The algorithm proposed in [2], is such a case. Their proposed algorithm consists of two phases. In the algorithm's first phase each node broadcasts its unique identifier. Consequently, when this message is received by the neighbor-nodes they would save the received identifier of the node along with its estimated distance into their neighbor-list. In the second phase, while each node selects *K* nodes from its list, which is previously ordered based on the distance between the two nodes, a symmetric graph will be achieved. Authors have suggested using the distance-to-sink parameter. Moreover, a node which might become isolated should be included in its nearest Node-To-Sink list, that is, a node with less distance to sink. This assignment is done via information received from an interest message.

Also some of the works which have been done in the literature reveal the application of heuristic methods in topology control. In [3] authors have proposed an ant-based topology control algorithm which is based on the transmission power adjustments. They have declared that their proposed algorithm uses local information and adapts well with mobility. However, in case of minimizing the maximum power, ABTC may achieve COMPOW, which is subjected to few shortcomings. COMPOW [4] works well in situations where nodes are stationary. It maintains the network's connectivity. It also extends battery life and thus prolongs the network's life time and also reduces the transmission power. Unfortunately, in the cases where nodes are distributed unevenly, it may use more power due to a global reconfiguration needed while nodes join or leave the network. Also it has a significant message overhead which is an unlikely feature.

In [5] authors have proposed extensions to MI [6] and Yao graphs [7] in respect of mobility. Their proposed graph takes the nodes' mobility into account by means of choosing the slowest neighbor in the transmission range of a node. Nodes will adjust their transmission range according to various mobility parameters. These parameters are used instead of the distance parameters in order to minimize the node's transmission power. However, the effect of parameters such as motion is not studied in this article and has been left as a future study criterion.

A similar algorithm to *K*-Neigh is the XTC algorithm [8]. It orders a node's neighbors based on a quality metric and then chooses its best neighbors based on that criterion. By contradiction, it is proven that the resulting graph is symmetric and does not need a forced symmetric phase which is necessary in the most of topology control algorithms and will be need eventually. XTC is also executed locally and thus does not need the exact location information of each node.

A topology control algorithm has been proposed in [9] that maintains the *K*-connectivity. The algorithm has three phases. In its first phase, each node broadcasts its location along with its ID and maximum power. Consequently, every neighbor node will reply this message with a similar message. Henceforth, every node will initiate a distributed algorithm in order to construct a vicinity graph indicating links between the nodes. In the second phase of the topology control, based on an optimality criterion, a topology will be constructed. Authors have studied the construction of topology in respect of a function consisting of: cost of path, maximum edge cost and also the number of hops. These criteria will be used later in the third phase in which each node will adjust its own power. Later, it will send a message to its vicinity nodes regarding the estimated power necessary for them to reach this particular node. Upon receiving this message, if a node's power is less than what is contained in this message the node will readjust its power. Authors argued that through some adjustments, this algorithm is capable of ensuring the correctness while nodes are mobile. However, they have assumed that each node is equipped with an omnidirectional antenna and thus is exactly aware of its location.

In [10] authors have proposed a very similar algorithm. Likewise, the proposed algorithm initiates with distributed broadcast of location and maximum power via each node. Later, each node collects replies from its nearby neighbors with a similar construction. Henceforth, a weighted graph is constructed in which weights are demonstrator of power assigned to edges containing that path in order to reach each other. Note that, paths are directional and thus weights assigned to adjacent nodes may differ. Furthermore, the algorithm may execute a relative algorithm such as Bellman–Ford in order to find shortest path in the aforementioned graph. Later, each node will adjust its transmission power and also will estimate the transmission power needed for its future neighbor nodes to reach it. Consequently, nodes will decide whether to readjust