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Energy based Techniques for Algorithms in MANETs: A Study

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Abstract— Environment created by mobile ad hoc networks (MANETs) emerges as miscellany of wireless nodes which forms a network for a short span without any assistance of centralized infrastructure. As the scenario is not fixed, nodes rely upon battery, which depletes with time. This arise the dilemma of energy as a constraint in MANETs. This paper confers on the approaches configured for minimizing the use of energy in such condition. Various techniques taken into account are transmission power control, load distribution, power management, sleep mode. The ultimate application of natural engineering to combat energy consumption is an addition to such schemes. Further, each area is described by corresponding recent algorithms which tend to portray a clear picture of their usage.

Keywords— energy efficiency, energy aware algorithms, mobile ad hoc networks, power saving techniques.

I. Introduction

Mobile ad hoc networks (MANETs) imitate a highly changeable and movable atmosphere. Being ad hoc in nature, each node participating in network has many roles assigned, that is of a receiver, transmitter and router. Hence, energy in abundance is expected to be expended on each role to achieve normal working of MANETs. But mobility factor of this infrastructure-less administration forces the nodes to confide on battery energy. Battery being a limited entity fails to fulfill the high demand of energy availability with time [1].

Under these circumstances, it is important that power utilization be managed efficiently by identifying ways to use less power, preferably with no impact on the applications. Scarcity of battery life, and the additional energy requirements for supporting network operations (e.g. routing) inside every node, make the energy conservation one of the peer concern in ad hoc networking [2]. The importance of this fix has produced a great deal of research on power saving techniques in wireless networks [3], and specifically in ad hoc networks [4]. Strategies for power saving which have been investigated at several levels of a mobile device, including the physical-layer transmissions, the operating system, and the applications [5], points out battery properties that impact on the design of battery powered devices.

The growing need for energy efficiency in wireless networks, in general, and in mobile ad-hoc networks (MANETs), in particular, calls for power enhancement features. There are active communication energy techniques [6] that can be categorized as Transmission Power Control, Load Distribution and Power management and inactive communication energy minimizing takes up the sleep mode approach [7]. Apart from this, Natural Engineering [8] approach has also contributed with its nature gifted ways to conserve energy for energy depreciating environments like MANETs.

The crunch of energy deficiency in MANETs leaded to emergence of efficient algorithms to save the energy for better network lifetime. Energy efficiency [9] plays a vital role in the construction of efficient algorithms and efficient operations need to be carefully built up to enhance the network lifetime. Therefore, the studying the energy aware algorithm strategies become a vast area to be researched in the field of ad hoc networks.

Before taking into account the algorithmic procedure, the metrics need to be reviewed which impact the energy efficiency. One of the metric which has its effect on energy in MANETs is nodal energy level [10]. If the nodal levels are known prior to routing decisions, the energy constrained nodes will get eliminated, which helps in a longer duration of network communication. Minimize energy consumed/packet corresponds to the average energy consumed per packet. Through this evaluation of energy conservation schemes will be easier. Adding to it is the gross cost of sending a packet along some path which can be computed as the sum of node costs along that path. This Minimize cost/packet metric is generally used if we are trying to derive an algorithm that maximizes the life of all nodes in the network [9].

II. Energy Aware Algorithm Schemes

Bifurcation of approaches for minimizing energy consumption can be done according to active and inactive communication [6]. To curtail the active communication energy there are three schemes power management, transmission power control (TPC), and load distribution respectively. Whereas, to cut rate energy use during dormancy of nodes sleep/power down mode is used.

To join these techniques, Natural Engineering [8] approach has also contributed with its nature giving solutions to conserve energy for energy hungry environments like MANETs. From years researchers are working on nature inspired routing protocols which have eliminated several problems in the area such as battery life, scalability, maintainability, survivability, adaptability and so on[11]. *Figure1* exhibits the clear classification of techniques used, also a detailed illustration of each approach is given below with examples.

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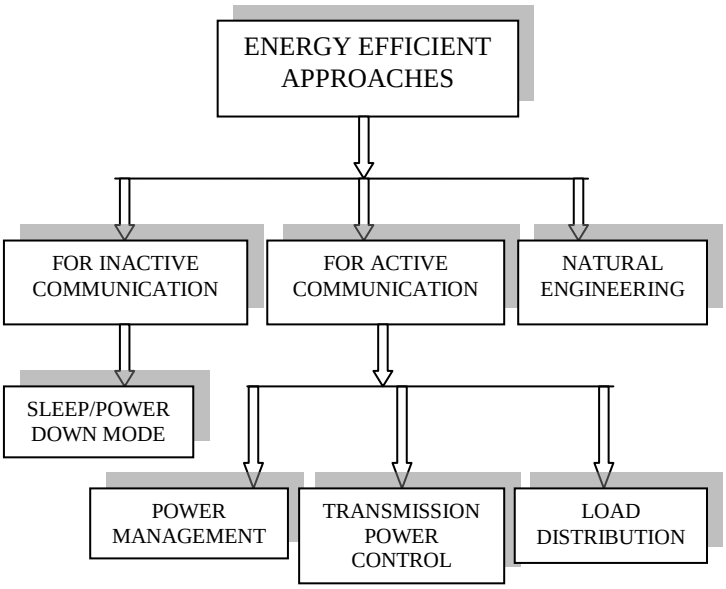

Figure 1. Division of energy minimizing processes

A. *Power Management Approach*

One way to combat the problem of energy deficiency is to minimize the power consumed by mobile devices. The idea [12] relies on the concept of triggering the nodes from high power mode to low power, which eventually leads to saving of energy. For efficient power management mechanism following spheres need to be considered:

- Which nodes will participate for power management process?
- When to switch an active node to its sleeping mode?
- The duration of an inactive node to remain dormant.
- Minimum delay criteria between source and destination needs to be fulfilled in comparison with all nodes active.
- The algorithm used for power management needs to follow distributed fashion.
- As an idle node in active mode consumes same amount of energy as an active transmitter, therefore it should be necessary that algorithms allows as many nodes as possible to switch off their radio receiver.
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Working of power management scheme can be explained more by taking two algorithms exhibiting this design. Brief description of these algorithms is given below:

1) Minimum power consumption and maximum network lifetime

This is the most recent energy efficient algorithm [6] which is based upon the threshold selected for each node. This threshold value further enforces the node having less energy to switch to sleep mode, henceforth gets excluded from the process of making routing decision for a packet. The key points considered in the algorithm design are:

- The process of deciding the minimum power consumption route is dynamic due to nature of MANETs and is done in advance.
- Node having less power but above the threshold value is considered in the process.
- Through periodical invigilation the residual energy of nodes are checked in accordance with threshold value. If it goes beyond the required level, the node enters sleep mode and an alternate node is selected for transmission.
- In order to support equal power consumption by all nodes, messages transmitted are of equal length. The author resolved the issue of power optimization and maximized network life with this algorithm.

2) Probability based Node Selection Method

It is a probability based algorithm which identifies the intermediate nodes that can bear the duration of connection. Hence, these nodes need to have than optimum stored energy to fulfill the condition. The author takes up a new parameter known as energy distance factor. The factor works by finding the best next hop node for optimizing the energy efficiency in MANETs, as described in [13]. Each nodes in MANETs has different energy levels, therefore residual energy also plays an imperative role in selecting the intermediate nodes. Taking into account these two metrics i.e. distance factor and residual factor, the probability of intermediate node is determined. This algorithm has a potential to prevent the early failure of a node, consequently adding to reliability of route path.

B. *Transmission Power Control*

TPC is one of the well known approaches used to save energy for wireless Ad-hoc networks. Reference [14] defines TPC by taking up a transmitter node X. It is stated that for a given data transmission rate R, the node X keeps its transmission power to a receiving node Y as low as needed for satisfying a target bit error rate E at the receiving node. Hence, by reducing the transmission power of nodes can lead to increase in network capacity.

The transmission power adjustment helps in maintaining a connected topology using the minimal power. So, the routing protocols based on controlling the transmission power are eligible to find best route which minimizes the total power between source and destination pair. Here transmitting power of mobile nodes [12] is adjusted in accordance with**:** signal-to-interference and noise ratio (SINR) of the transmitting or receiving nodes, and distance between transmitter and receiver. TPC based algorithms are discussed below:

1) Least battery-powered node routing algorithm

LBNR [14] defines a set of energy-aware routing algorithms which take up kind of power supply of nodes and their consumed energy for transmission and reception of packets

over wireless links to calculate the energy cost of routes. In the sequel, these are LBNR–LM and LBNR– WSA algorithms.

2) Minimum battery cost with least battery-powered nodes routing algorithm

MLNR [14] are group of energy-aware routing algorithms which take up type of power supply of nodes, the energy consumed by nodes for packet transmission and reception over wireless links, and the remaining battery energy of nodes to calculate the energy cost of routes. In the sequel, these are MLNR–LM and MLNR–WSA.

3) Variable range energy aware location routing (ELAR1-VAR)

This algorithm was designed to control transmission power of node with respect to the distance between the nodes. The algorithm stated in [15] has taken advantage of location information usage characteristic of LAR1. As LAR1 sets the path from source to destination by using the location information, it is taken up as a critical factor for designing variable range technique.

Here overall energy consumption of network is reduced by taking up the technique of variable transmission power control. The information in RREQ (route request) packet of LAR1 is used to compute the distance between nodes. Furthermore, energy factor (proposed in [16]) has been introduced for the selection of energy efficient path.

C. Load Distribution Approach

Balancing the usage of energy in each node by choosing a path with underutilized nodes rather than shortest route is the main objective of this approach [12]. Although, it leads to longer routes, but routes are energy conserving as energy rich intermediate nodes are used. This process can seen more of load shedding task as it do not necessarily provide lowest energy path, but gives relief to overburdened nodes which happens to make longer network lifetime. A load distribution algorithm is taken up below to explain the process through example:

1) Local energy aware Ad-hoc On demand vector routing (LEA-AODV)

It was proposed by [17] to balance energy consumption within all participating nodes. The task is carried out through local information gathered by the node. Accordingly, the node decides whether to participate in the selection process of route. Here the node having less energy conserves it by not forwarding the data packets which are not intended for it. This procedure is developed to increase the network survivability because the network connectivity is maintained.

D. Sleep/Power Mode Approach

This division focuses on inactive time of communication. With the emergence of low power states supported by hardware, it becomes essential to utilize them to save energy. Specifically in scenarios like MANETs, where energy as a resource has always been deficient.

In sleep mode [12], all nodes get inactive and packets cannot be delivered to a destination node. To overcome this problem, a master node is introduced. So, this node can coordinate the communication between the remaining slave nodes. Environments where the network is big such as multi hop MANET, more than one master node has to be introduced for convenience. This concept emerge out to be a master-slave network architecture, where except the master nodes, all nodes switch to energy saving mode i.e. sleep mode. Periodically these slave nodes get active to check out for any message from master node. If the master node is idle, they again switch to sleep mode.

This architecture is deployed in two ways. The foremost one is based on symmetric power model, in which the radio power of master and slave is same, accordingly having same transmission range. The latter is based on asymmetric power model. The model consists of master nodes having longer transmission range than the slave nodes. Both scenarios are clearly exhibited in figure2 [12].

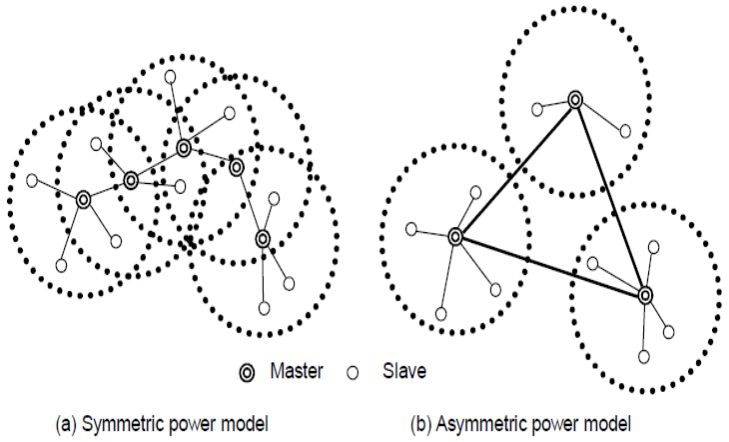

Figure 2. Master-slave MANETs architecture

E. Natural Engineering

Nature gifted solutions through ants, bees, wasps and birds have contributed in building up energy efficient algorithms. Here are two algorithms based on the foraging behavior of insects to lessen the energy consumption:

1) Bee Ad-hoc algorithm

It is one of the evolutions of natural engineering process which takes up the foraging behavior of honey bees to achieve

the performance. Also, it is achieved at a significantly lesser energy expenditure as said in [8]. The core reason behind the energy efficiency feature of the algorithm is the simplicity of message types used. There are only two types of messages involved for routing:

- Scouts: the one are responsible for on demand discovery for new routes to destination.
- Forgers: the one who take care for transporting data packets along with evaluating the quality of discovered routes.

The algorithm exhibited a better performance when author compared it with DSR, AODV, and DSDV in terms of energy efficiency, that also without making any adjustments on traditional performance metrics.

2) Energy aware ant based routing algorithm (EAAR)

The ant inspired algorithm [18] encounters the problem of energy aware routing in ad-hoc networks. It takes up the characteristics of Ant Colony Optimization [19] in which naturally occurring efficient foraging behavior of ants help in decision making process. In this, the path discovery is accomplished by taking up the minimum battery energy remaining in the weakest node of the path and the hop count of the route as metrics.

Taking up the hop count, the author [18] noticed that the number of hops was directly proportional to the energy consumed i.e. more the number of hops, greater will be the transmission, and eventually more will be the energy consumption. Adding to it, the minimum battery energy remaining concept was helpful in finding the energy aware paths. As the good routes were considered, the dead nodes got reduced. For this multipath transmission was applied to the good routed only. The benefit of taking multipath routing was to achieve load balance of the traffic.

In brief, EAAR achieved energy efficiency because of following attributes:

- Multipath routing
- Path discovery with co-ordinance with ACO properties.
  Good maintenance of path and backup mechanism.

III. Conclusion

The purpose of this study was to understand the layout of energy aware routing strategies. Various approaches to encounter the energy deficiency in MANETs were discussed, which will contribute in giving a clear image of energy saving algorithms.

A new prospective in bifurcating the process of designing energy based algorithms was considered, which is known as natural engineering, along with the already existing techniques i.e. minimizing energy in active and inactive communication. Most of the algorithms briefed out in the study are latest and need to be explored more in future. Security parameters can be added up for robust mechanisms.

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