

# Ant replication: Saving power expenditure in MANETs

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## Abstract

*Mobile ad hoc networks (MANETs) require no fixed infrastructure, thus allowing dynamic networks to be created whenever and wherever required. This advantage is not only of huge benefit for military/rescue operations but would also be similarly advantageous in the industrial and educational sectors. However, MANETs are not without their drawbacks. Routes may frequently be broken without notice, due to nodes moving out-of-range, or from the mobile device containing the node being switched off or if power expires. Due to the need for economies in power expenditure, reactive routing protocols are favoured over those that are proactive as nodes are only activated when a route is required. Proactive protocols that keep routes continuously updated will in turn exhaust the batteries of the mobile devices. This paper proposes that power saving can be achieved at the route discovery phase in relation to the routing hybrid protocols involving the use of ants. We will demonstrate that by splitting ants and recovering their history we will achieve efficient power saving as oppose to global ants routing.*

## Keywords

Mobile ad-hoc network, ant replication, splits, energy-efficiency, power saving, route discovery

## 1. INTRODUCTION

With the advent of wireless networks, as their popularity increases, not only in industry but also for educational and home use, interest is now turning to mobile ad hoc networks (MANETs). Unlike wireless networks, MANETs do not require infrastructure support and the mobile nodes, which act, as both host and router, are autonomous. These nodes may join and leave the network at will which make MANETs especially advantageous in disaster zones (earthquakes, floods) where networks infrastructures have been destroyed or for rescue operations (sea, mountain) where there is no infrastructure.

The nodes are embedded into devices such as laptops, mobile phones, PDAs and may even be integrated into clothing (an idea which is not far from fruition) therefore indicating that the majority of nodes forming the MANET are battery operated. Although these batteries are re-chargeable, the environments in which such networks are formed means that the energy supply required for re-charging is not constantly available. Hence it follows that MANETs have a finite power supply, thus energy conservation is of paramount importance. Due to the nature of MANETs where nodes may be leaving due to travelling out-of-range or being switched off, it is essential to the network's success that as few nodes as possible are lost because of power failure. A way of achieving this, and an area in which much research is being undertaken, is to ensure routing protocols are as energy efficient as possible.

Toh's [1] CMMBCR (Conditional Min-Max Battery Cost Routing) has combined the features of two energy-efficient protocols namely MMBCR [2] and MTPR [3], to provide a hybrid protocol, which uses two conditions in order to select the most energy-efficient route to take. Briefly, MMBCR and MTPR function in the following ways:

MMBCR – determines its condition on the residual power levels of each individual node within sets of routes. Attention is given to the weakest node of each route, that is, the node with the least amount of power left. The route to be used is the one whose weakest link is the strongest when compared to all the other routes' weakest nodes. Basically, by avoiding the very weakest nodes unless they are critically needed increases the network's lifetime. Where MMBCR considers individual node power capacities in order to ascertain the route to take, MTPR studies the power requirements of routes as a

whole. The routes using the least amount of power are the ones with short hops between nodes, as opposed to the longer hop routes. However, the route(s) using short hops may incur a greater number of intermediary nodes between source and destination and although they may be favourable in terms of energy cost, the probability of nodes with low residual power capacity being used, increases. This could inevitably result in weaker nodes being frequently used, possibly to the point of power exhaustion and resulting in their departure from the MANET causing damaging breaks.

CMMBCR has encompassed the benefits from both these protocols. Initially, CMMBCR has a pre-determined level of acceptable power capacity and if the nodes within the routes are greater than or equal to this level, the MTPRs condition is applied. However should nodes within all the routes fall short of CMMBCRs level, using a weak node is unavoidable and it is therefore advantageous to the network to use the route with the strongest of these nodes. Hence, the protocol MMBCR is applied.

These protocols are concerned with energy efficiency in the transmission of packets across the network. This paper proposes power saving during the route discovery phase at node level. Generally it is felt that reactive protocols should be favoured over proactive ones as power expenditure is only used when a route is required as opposed to using valuable power to determine routes, which may not be used. However, in the case of MANETs, table-driven (proactive) protocols are advantageous in keeping routes up-to-date and correct; taking in changes brought about by the nodes mobility. Hence, various hybrid routing protocols have been developed where a proactive protocol is used alongside a reactive one. A number of these use ants (proactive) for example, Ant-AODV [4] and AntNet [5]. It is within this context that considerable power saving can be achieved.

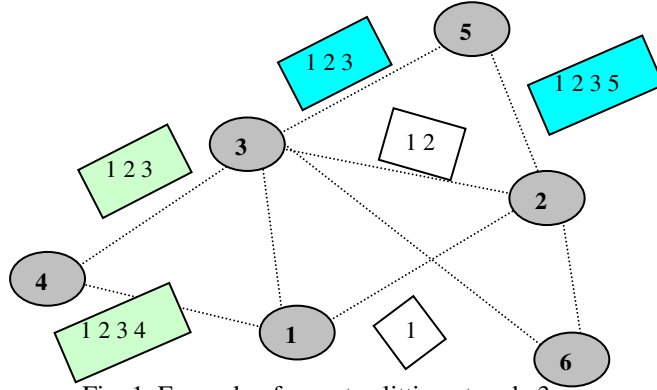


Fig. 1. Example of an ant splitting at node 3

## 2. ANALYSIS OF POWER CONSUMPTION

We will show in this paper that power consumption can be considerably reduced by having the route-discovering ants split once their node history has reached a pre-determined count. This second ant will be a replica of its 'parent', hence each will possess identical node histories, see fig. 1. Thus at this point, their node histories will have been acquired using only half the power consumption usually required. Post-split, the ants will work independently and power expenditure returns to the level of the currently proposed ant routing protocols. Using the ratio of ants to nodes as 1:2, it is assumed that the majority of nodes will be in active mode, so power required to activate a sleeping node is not being taken into consideration. In the following subsections we will compare the power consumption between splitting and non-splitting ants in a wireless network. We will denote the powers in each case as  $P_s$  and  $P_{ns}$  respectively. Throughout this paper we will be interested in the percentage of the power saving between the two techniques by computing  $P_r \% = (1 - P_s / P_{ns}) * 100$ .

The following notations are used throughout the analysis of the power consumption.

$A_{ij} = P_{tij} + P_{rij} + P_{pij}$  is the power consumed by every node visited by an ant, where  $P_{tij}$ ,  $P_{rij}$  and  $P_{pij}$  represent the transmitting, the receiving and the processing powers respectively. Depending on the history of an ant, the consumed power of each node in the network may be different.

$V_i$  denotes the number of visited nodes before two consecutive ant splits.

$U_{ij}$  denotes the number of visited nodes by an ant after which the ant vanishes due to insufficient power in the transmitter or the receiver has moved out of range, where  $i$  is the level of split and  $j$  is the path taken in that level by an ant.

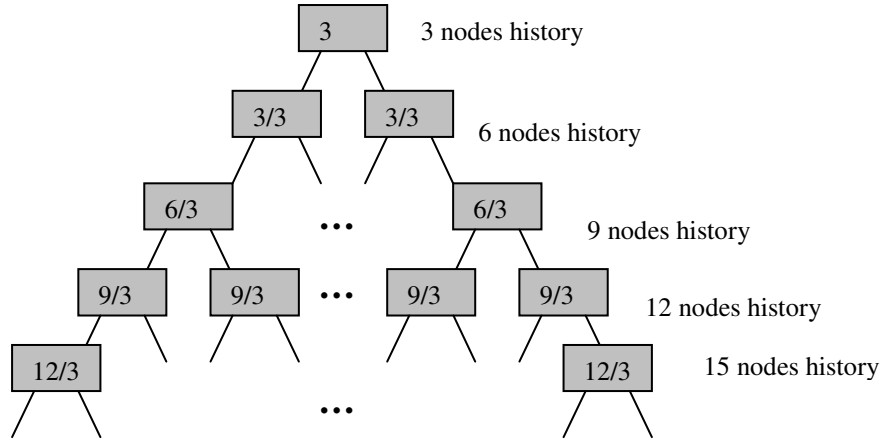


Fig 2. Ants splitting on a node history count of 3

In general, using fig. 2, one can deduce the powers consumed with and without the ant splitting as

$$P_s = \sum_{k=1}^{U_{01}} A_{0k} + \sum_{i=1}^n \sum_{j=1}^{2^{i-1}} \left\{ \begin{array}{l} \left( \sum_{k=1}^{U_{i,2^{j-1}}} A_{ik} + \sum_{k=1}^{U_{i,2^j}} A_{ik} \right) \text{ if } U_{i-1,j} = V_i \\ 0 \end{array} \right\} \quad (1)$$

$$P_{n_s} = 2^n \sum_{k=1}^{U_{01}} A_{0k} + \sum_{i=1}^n 2^{n-1} \sum_{j=1}^{2^{i-1}} \left\{ \begin{array}{l} \left( \sum_{k=1}^{U_{i,2^{j-1}}} A_{ik} + \sum_{k=1}^{U_{i,2^j}} A_{ik} \right) \text{ if } U_{i-1,j} = V_i \\ 0 \end{array} \right\} \quad (2)$$

where  $\mathbf{n}$  is the number of splits or simply called in this paper the number of levels. Between each level an ant may visit  $U_{ij}$  number of nodes after which it will vanish or  $V_i$  number of nodes after which it splits to generate the next level. In general for a network with multiple sources the above equations are summed up to cover all the paths visited by the ant in the network.

## 2.1 Ant splitting and reaching maximum node history

Although initially the concept of having ants split at a certain point would help to make ant protocols more energy efficient, it also appears to provide a possible solution to the loss of the ant population as noted by Marwaha et al [4]. An expansion of the notion of ants splitting at a certain node history count would be to have the ants split on a regular count, for example, on history of three, see fig. 2 as an example. The following calculation considers the power saving ( $P_r$ ) percentage achieved in terms of power consumption for the reception and transmission of the ants when splitting, refer to fig. 2. On transmission of the second ant, the ant will select a random hop different from the one it has originated from. By setting  $U_{ij} = V_i$  in equation 1 and 2, and computing the gain in power consumption for ant splitting with maximum history, we can deduce the following equation.

$$P_r \% = \left( 1 - \frac{\sum_{i=0}^n 2^i \left( \sum_{j=1}^{V_i} A_{ij} \right)}{2^n \sum_{i=0}^n \left( \sum_{j=1}^{V_i} A_{ij} \right)} \right) * 100 \quad (3)$$

There are several cases related to the number of visited nodes and the amount of consumed power per nodes that can be studied from this equation. In the following cases we will describe, possibly, the most common ones.

Case 1:

In this scenario we assume that all the nodes between two consecutive splits or within a level consume the same amount of power,  $A_{ij} = A$ , with equal number of visited nodes between the splits,  $V_i = V$ . Applying this assumption to equation 3 and after some mathematical manipulations the result is

$$P_r \% = \left( 1 - \frac{2^{n+1} - 1}{2^n(n+1)} \right) * 100 \quad (4)$$

Case 2:

In this scenario we assume that the power in each node increases by a factor of  $\mathbf{A}$  every time an ant visits it, due to the accumulation of the ant history. This can be proved when the number of visited nodes between splits is fixed, the consumed power for each level is

$$\sum_{k=1}^V A_{ik} = AV^2i + \frac{AV}{2}(1+V) \quad (5)$$

where  $\mathbf{A}$  is the consumed power of the source node that originated the ant, and  $\mathbf{V}$  is the constant distance in term of nodes between two consecutive splits. By using equation 5 in equation 3, and after some mathematical manipulations, we can deduce the gain in power consumption as

$$P_r \% = \left( 1 - \frac{2^{n+1} - 1 + \frac{4V}{1+V}(1 + (n-1)2^n)}{2^n \left[ (n+1) + \frac{nV}{1+V}(n+1) \right]} \right) * 100 \quad (6)$$

## 2.2 Ants splitting possibly without reaching maximum node history.

The above equations give the theoretical power saving, as it assumes that all the ants ‘live’ to their full node history before being deleted from the network. However, taking into consideration Marwaha et al’s [4] observations of ants diminishing at a considerable rate from the network, thus implying full node histories are not collected by all the ants, as deduced in equations 1 and 2 for the general cases.

Case 3

In this scenario we assume that there is a single split,  $\mathbf{n=1}$  and the power consumption per node increases by a factor of  $\mathbf{A}$ , refer to equation 5. Fig. 4 in the results section will show the power saving for this case.

## 3. RESULTS

As fig. 3 shows, with case 1 the resultant power saving would be 72% with up to 6 splits. In this case, the power saving is independent of the number of nodes visited within each level, and almost increases linearly with the number of splits. However, in case 2 where the power consumption increases each time an ant traverses the network, the gain in power consumption is slightly depending on the number of visited nodes in each level. As such negligible differences in power saving are achieved by varying the number of nodes within the levels, it would seem to be more advantageous to have a lower number of nodes per level, as this would facilitate a higher degree of individuality within an ants node history. For case 3, we assume that the network contains 100 nodes with a maximum number of 50 sources, the maximum node history is set to 15 after which the ants are deleted, with the split occurring at node count 5. Therefore the maximum number of nodes visited per source would be 25. On average, as shown in fig. 4, a gain of 13% could be achieved. For larger numbers of splits one would expect a greater saving in power consumption, to be around 50% for 6 splits, as shown in fig. 3.

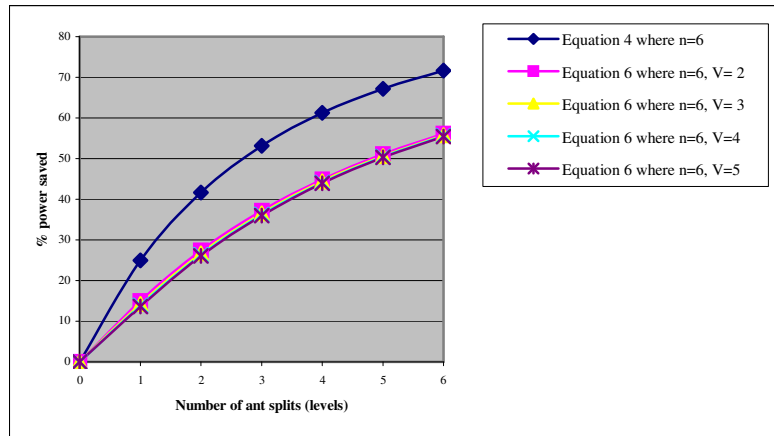


Fig. 3. Power savings achieved at each level

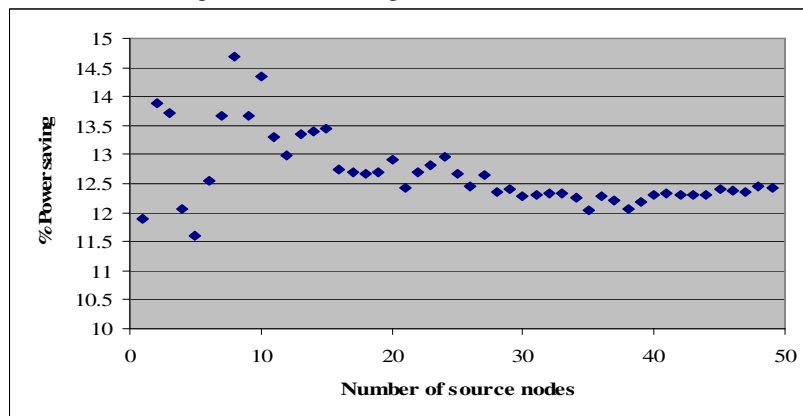


Fig. 4. Power savings achieved when ants split once only

## 4. CONCLUSION

This paper has shown that energy saving can be achieved at the route discovery stage when using routing protocols involving ants. Although proactive protocols are useful for MANETs, as they can keep up-to-date with the network topology, they are less favourable in terms of power expenditure when compared to reactive protocols. Ant replication produces results, which could make the hybrid proactive protocols a competitive option. It can be seen from the foregoing results that the higher the level an ant reaches within its lifetime, the greater the power saving. Ants, which split only once, produced the lowest percentages of power saving indicating that multiple splits are preferable. Within these splits, it can be seen that the lower the number of nodes involved, the better the yield of individual routes obtained. Additionally, a healthy ant population is more likely to be maintained.

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