Ant Colony Optimisation Algorithms for Solving Multi-Objective Power-Aware Metrics for Mobile Ad Hoc Networks

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Abstract

A mobile ad hoc network (MANET) is an infrastructure-less multi-hop network where each node communicates with other nodes directly or indirectly through intermediate nodes. Thus, all nodes in a MANET basically function as mobile routers participating in some routing protocol required for deciding and maintaining the routes. Since MANETs are infrastructure-less, self-organizing, rapidly deployable wireless networks, they are highly suitable for applications such as military tactical operations, search and rescue missions, disaster relief operations, and target tracking.

Building such ad-hoc networks poses a significant technical challenge because of energy constraints and specifically in relation to the application of wireless network protocols.

As a result of its highly dynamic and distributed nature, the routing layer within the wireless network protocol stack, presents one of the key technical challenges in MANETs. In particular, energy efficient routing may be the most important design criterion for MANETs since mobile nodes are powered by batteries with limited capacity and variable recharge frequency, according to application demand. In order to conserve power it is essential that a routing protocol be designed to guarantee data delivery even should most of the nodes be asleep and not forwarding packets to other nodes. Load distribution constitutes another important approach to the optimisation of active communication energy. Load distribution enables the maximisation of the network lifetime by facilitating the avoidance of over-utilised nodes when a route is in the process of being selected.

Routing algorithms for mobile networks that attempt to optimise routes while attempting to retain a small message overhead and maximise the network lifetime has been put forward. However certain of these routing protocols have proved to have a

negative impact on node and network lives by inadvertently over-utilising the energy resources of a small set of nodes in favour of others. The conservation of power and careful sharing of the cost of routing packets would ensure an increase in both node and network lifetimes.

This thesis proposes simultaneously, by using an ant colony optimisation (ACO) approach, to optimise five power-aware metrics that do result in energy-efficient routes and also to maximise the MANET's lifetime while taking into consideration a realistic mobility model. By using ACO algorithms a set of optimal solutions – the Pareto-optimal set – is found.

This thesis proposes five algorithms to solve the multi-objective problem in the routing domain.

The first two algorithms, namely, the energy efficiency for a mobile network using a multi-objective, ant colony optimisation, multi-pheromone (EEMACOMP) algorithm and the energy efficiency for a mobile network using a multi-objective, ant colony optimisation, multi-heuristic (EEMACOMH) algorithm are both adaptations of multi-objective, ant colony optimisation algorithms (MOACO) which are based on the ant colony system (ACS) algorithm. The new algorithms are constructive which means that in every iteration, every ant builds a complete solution. In order to guide the transition from one state to another, the algorithms use pheromone and heuristic information.

The next two algorithms, namely, the energy efficiency for a mobile network using a multi-objective, MAX-MIN ant system optimisation, multi-pheromone (EEMMASMP) algorithm and the energy efficiency for a mobile network using a multi-objective, MAX-MIN ant system optimisation, multi-heuristic (EEMMASMH) algorithm, both solve the above multi-objective problem by using an adaptation of the MAX-MIN ant system optimisation algorithm.

The last algorithm implemented, namely, the energy efficiency for a mobile network using a multi-objective, ant colony optimisation, multi-colony (EEMACOMC) algorithm uses a multiple colony ACO algorithm.

From the experimental results the final conclusions may be summarised as follows:

- Ant colony, multi-objective optimisation algorithms are suitable for mobile ad hoc networks. These algorithms allow for high adaptation to frequent changes in the topology of the network.

- All five algorithms yielded substantially better results than the non-dominated sorting genetic algorithm (NSGA-II) in terms of the quality of the solution.
- All the results prove that the EEMACOMP outperforms the other four ACO algorithms as well as the NSGA-II algorithm in terms of the number of solutions, closeness to the true Pareto front and diversity.

Thesis supervisor: Prof. AP Engelbrecht
Department of Computer Science

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Finally, I would like to dedicate this research to my dear sister–in–law who died unexpectedly at a young age recently leaving behind five children.

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