Investigation of antnet routing algorithm by employing multiple ant colonies for packet switched networks to overcome the stagnation problem

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Abstract - Antnet is a software agent based routing algorithm that is influenced by the unsophisticated and individual ants emergent behaviour. Ants (nothing but software agents) in antnet are used to collect traffic information and to update the probabilistic distance vector routing table entries. One of the major problems with antnet is called stagnation and adaptability. This occurs, when the network freezes and consequently the routing algorithm gets trapped in the local optima and is therefore unable to find new improved paths. There are several methods to overcome stagnation problem such as noise, evaporation, multiple ant colonies and using other heuristics. In this paper, multiple ant colonies are applied to the packet switched networks and results compared with the antnet employing evaporation. Results showed that employing multiple ant colonies has no effect on the average delay experienced per packet but it has improved the throughput of the network slightly.

1. Introduction

In today's fast growing Internet traffic conditions changes and failures occurs at some parts of the network from time-to-time, in an unpredictable manner. Therefore, there is a need for an algorithm to manage traffic flows and deliver packets from the source to the destination in a realistic time. An ideal routing algorithm should be node and link independent, and be able to deliver packets to their destination with the minimum amount of delay, regardless of the network size and the traffic load. The routing algorithms currently in use lack intelligence, and need human assistance and interpretation in order to adapt themselves to failures and changes. In recent years, agent based systems and reinforcement learning have attracted researchers interest. This is because these methods do not need any supervision and are distributed in nature.

The ant-based approach applied to routing problem was first reported in [1]. This work was influenced from the work done on the software agents used for control in telecommunication networks [2]. Improved version of the algorithm in [1] was applied to the connection oriented systems [3]. Then for the first time ant based routing was applied to the packet based connection-less systems [4]. This was followed by a mobile agents approach to adaptive routing in [5].

Although ant based routing algorithms have shown some interesting results, they are still far away from being ideal. One of the major problems is that the network freezes and consequently the routing algorithm gets trapped in the local optima and is therefore unable to find new improved paths. This is also called stagnation or adaptability problem [6], which has been studied by many researchers. A number of methods have been proposed to overcome this problem. Such as: evaporation, multiple ant colonies, aging, pheromone control and hybrid algorithms. However, most of these are rather complex and requires other heuristics. Here, the focus is on multiple ant colonies. This paper applies multiple ant colonies to the packet switched networks and compares its results with evaporation [7]. In multiple ant colonies, it is assumed that there are more than one ant colony exists where every colony has its own pheromone tables. On the other hand evaporation uses the idea of evaporating the probabilities assigned to the every link based on a statistical variables held at every node in regular intervals.

2. Antnet Routing Algorithm

Antnet [5, 8] is an agent based routing algorithm that is influenced from the real ant's behaviour. In antnet ants explores the network to find the optimal paths from the randomly selected source destination pairs. Moreover, while exploring the network ants update the probabilistic routing tables and construct a statistical model of the nodes local traffic. Ants make use of these tables to communicate with each other. The algorithm uses two types of ants namely, forward ants and backward ants to collect network statistics and to update the routing table. In each node there are two types of queues, low priority and high priority. The data packets and the forward ants use low priority queues, whereas the backward ants use the high priority queues. Later forward ants do also use the high priority queues [5, 8].

Ants communicate through two data structures stored in every node (see Fig. 1) as outlined below [5, 8]:

i. A distance vector routing table T_k with distance metric defined with probabilistic entries where for each possible destination d and neighbour node n there is a probability value P_{nd} that reflects the goodness of the link (path), given as:

$$\sum_{n \,\varepsilon\, N_k} P_{nd} = 1,\ d\ \varepsilon\,[1, N],\quad N_k = \{Neighbours(k)\} \qquad (1)$$

An array M_k (μ_d, σ_d^2, W_d) defines a simple statistical traffic model experienced by the node k over the network. Where W_d is the observation window used to compute the estimated mean μ_d and the variance σ_d^2 parameters [1] given as, respectively:

$$\mu_d = \mu_d + \eta(o_{k\to d} - \mu_d) \tag{2}$$

$$\sigma_d^2 = \sigma_d^2 + \eta((o_{k\to d} - \mu_d)^2 - \sigma_d^2) \tag{3}$$

$O_k \rightarrow d$ is the new observed trip time experienced by the agent while travelling from node k to destination d. Detailed algorithm description can be found in [5, 8, 9].

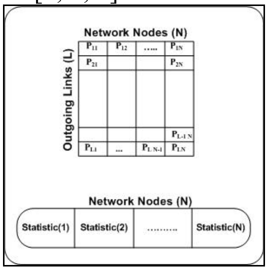

Fig. 1. Probabilistic routing table and traffic statistic.

3. Evaporation

When a network reaches to its equilibrium state stagnation occurs. This is an undesirable property also caused by ants recursively choosing the same path in antnet routing algorithm. Therefore, routing optimisation may get stranded in the local optima and may not be able to discover new paths that became optimal due to the changes in network traffic and topology (i.e. due to link/node failures or deleting/adding new nodes). Moreover, finding the shortest path by the ants is a statistical process [10]. In the beginning if ants choose a non-optimal path, the probability of other ants following them increases. Several methods such as aging, limiting amount of pheromone laid, evaporation, multiple ant colonies and using other heuristics beside ant colony optimisation have been used and studied in the literature [6].

Evaporation is a real life scenario where pheromone laid by real ants evaporates in time due to natural circumstances. Evaporation rate $E(x)$ is defined as:

$$E(x) = \left[1 - \frac{ant\_send(x)}{\sum_{i=0}^{N} ant\_send(i)} \right] x P(x) \tag{4}$$

Equation 4 represents the reduction in the probability from a link to a neighbour x. It is the proportion of number of forward ants destined to the node x over the total ants received by the current node in the given time window. Variables that keep track of the number of ants forwarded to the neighbours are cleared after a specific time period.

The probability of evaporation can be defined as:

$$P(i) = P(i) - E(x), i = x \tag{5}$$

Since, for all N, the sum of all probabilities is equal to 1, then probability of evaporation from node x distributed equally to the other neighbours is given by:

$$P(i) = P(i) + \frac{E(x)}{N-1}, i \neq x \tag{6}$$

4. Multiple Ant Colonies

The idea of using multiple ant colonies was first applied to the wavelength routing in [11]. In their work, more than one ant colonies are used in order to distribute the different wavelengths over the network to achieve increased availability for the required wavelength at any given time. In the original antnet ants are only attracted by the pheromone trails laid by the ants from their own species. In addition to this, in [11] ants are repelled by the pheromone laid by other species. Therefore, routing decision implementation is based on more than one routing table. Three variants of algorithm have been proposed namely: local update, global update/distance and global update/occupancy. In local update table entries are updated in every hop whereas, in global update table

1 η weights the number of samples that affect the average and set to 0.05[10].

entries are updated at the end of each cycle[2]. Also, two variants of global update have been used where two different repulsion techniques are used to distribute the wavelengths based on the distance or the link occupancy. In multiple ant colony optimisation (MACO) has been taken steps further by applying the idea of multiple ant colonies to the antnet routing algorithm in the circuit switched networks. In [12] it is assumed that there exists more than one ant colonies. Let's say there are two ant colonies exists in the network named as red and blue, where each use different pheromone tables. For example, red ants only update the pheromones laid by the red colonies and so on. By using two colonies, more than one optimal path becomes available for every source destination pair. Therefore, higher load balancing is achieved. Unlike [11], where ant colonies repel each other, in [12] there is no information given whether ant colonies repel or attract each other. To date application of multiple ant colony algorithms to the packet-switched networks has not been reported, and consequently there is no performance evaluation.

5. Simulation Results

Evaporation criteria and multiple ant colonies [7] are applied to the modified antnet routing algorithm [9] and are implemented in the environment shown in Fig. 2.

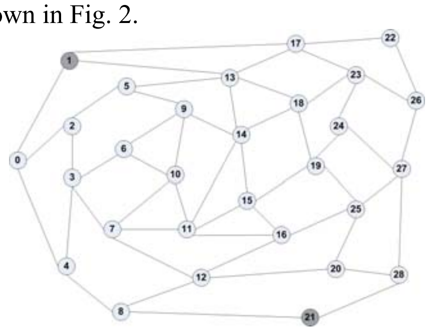

Fig. 2. 29Node random network.

Algorithms implementation process and assumptions made are as follows:

- C language in a parallel environment by using Parallel Virtual Machine (PVM).
- Parallel behaviour is simulated by assigning every process to a different node both on the same machine and different machines. Inter process communication mechanism is dealt by the system kernel whether processes reside on the same or different machines (i.e. need inter or intra process communication).
- Poisson traffic distribution is used on non-uniform data traffic where 50% of the traffic is forwarded to nodes 1 and 21 in different time intervals.
- No packet creation destined to the immediate neighbours.
- Five seconds are given to discover all the paths and to initialise the probabilistic routing table entries.
- Ant creation rate is set to 10 seconds per node.
- Random network topology with each link having equal cost is used, see Fig. 2.
- For each simulation, packet generation is stopped after creation of 2500 packets per node and simulation is stopped after all packets are arrived to their destinations or detected and deleted from the network.
- Every simulation is run 15 times and the average of the results is used for accuracy. It is assumed that the packet size is fixed and there is no packet loss.

Table 1 shows the results for the average delay experienced per packet, overall throughput of the network during simulations and the overhead caused by the ants travelling in the network for improved antnet [9], antnet with evaporation [7] and for antnet employing multiple ant colonies. The lowest delay experienced by the data packets is for the antnet employing evaporation, but at marginally higher agent overhead and lower throughput. Higher throughput has been achieved by the multiple ant colonies since there are more than one optimal paths that can be exploited by the ant colonies at any given time. In another word, when a path become optimal for a colony it becomes congested, therefore other colony needs to find another optimal path. Thus, the algorithm can achieve better load balancing and higher throughput.

	Multi Antnet	**Evaporation**	**Improved Antnet**
Average Delay (sec.)	2.121	2.033	2.118
Throughput (kbits/sec)	5698.966	5265.960	5277.300
Agent Overhead (%)	0.455	0.521	0.520

Table 1: Comparison of multiple antnet colonies, evaporation and improved antnet.

[2] An ant is said to complete its cycle when it completes it journey from source node to the destination node.

Fig. 3 shows the throughput of the network for improved antnet, antnet with evaporation and antnet employing multiple ant colonies. It can be seen that packet creation has stopped around 100th second (every node in the network stops creating packet after 2500 packet creation.). When network is congested multiple ant colonies performe better than the other two.

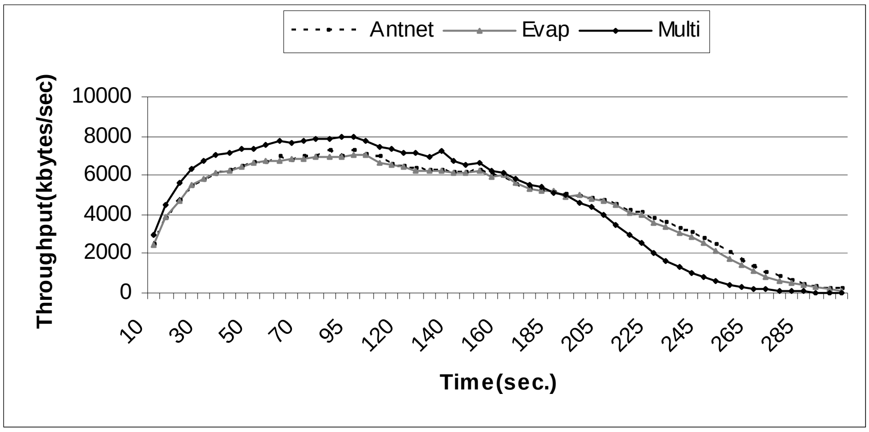

Fig. 3. Throughput characteristics for improved antnet, evaporation and multiple antnets.

6. Concluding Remarks

One of the major problems with the antnet is stagnation and adaptability. This occurs, when the network freezes and consequently the routing algorithm gets trapped in the local optima and is therefore unable to find new improved paths. There are several methods to overcome stagnation problem such as noise, evaporation, multiple ant colonies and using other heuristics. In this paper, multiple ant colonies was applied to the packet switched networks and results were compared with the antnet employing evaporation. It was shown that by employing multiple ant colonies in packet switched networks, throughput can be increased. On the other hand, no gain in average packet delay is observed. One major disadvantage of using multiple ant colonies is the resources used in every node. More colonies would be required (thus routing tables), when applying multiple ant colonies to larger sized networks in order to exploit more paths. In this work, no direct interaction among the different ant colonies was considered. Thus, methods used in [11] could be applied to improve the performance of multiple ant colonies in packet switched networks.

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