ENHANCED ANT COLONY OPTIMISATION IN NETWORKS

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Background

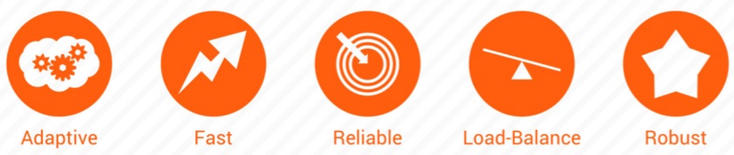
The traditional network routing algorithm Open Shortest Path First (OSPF) route packets along the path of the minimum cost from the source to the destination. However, this can cause congestion (along the minimum cost path).

AntNet [1,2] is an alternative routing algorithm that addresses the issue of congestion by distributing load amongst all possible paths.

Objectives

The greater the number of articulation points a network possesses, the worse AntNet performs. This is because it does not eliminate illogical choices for packets' next hops for a given destination.

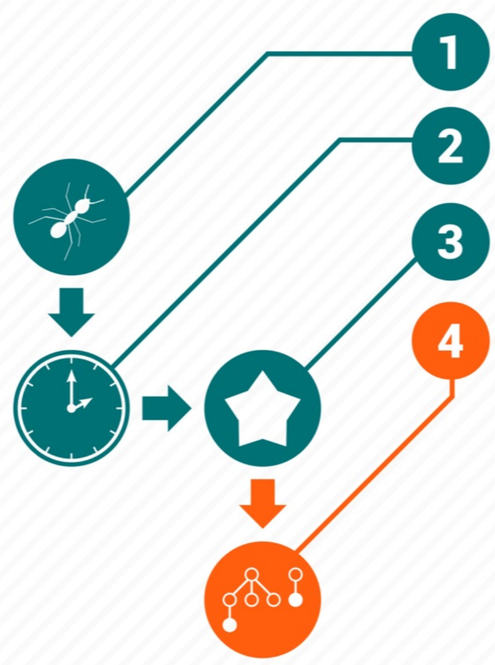
We aim to develop an algorithm that improves upon AntNet and provides robust load balancing, and show that it is superior to AntNet via simulations.



Aims of our algorithm

Methodology

We designed an algorithm based off AntNet, named Enhanced Ant Colony Optimisation (EACO), which makes use of disjoint-set data structures. Details of how the algorithm works are as follows:



1. At frequent intervals, nodes send ants to sample network load by recording travelling times.
2. Using estimated packet travelling time, the goodness of sending packets to a neighbouring node for a given destination is evaluated.
3. Packets are more likely to be sent to neighbours that are evaluated as being better.
4. Using disjoint-sets, neighbour nodes that are not viable* are ignored.

   We initialise several elements in a disjoint-set data structure, one for each node. For each link in the graph, we merge its endpoints, unless one of them is the current node.

   To detect whether a neighbouring node is viable for a given destination, we check if the two nodes are in the same set.

   A **viable node is a node that remains connected to the destination if the current node is removed from the graph.*

AntNet

Enhanced Ant Colony Optimisation (EACO)

Our improvements are key to better performance as:

1. The usage of disjoint-sets improves quality and speed of network evaluation as ants do not take useless detours.
2. There is also decreased latency, as packets also do not take useless detours.

Data Collection

For each network, we ran each algorithm with a single source and destination (highlighted lime) and uniform traffic, and benchmarked their average performance via several metrics:

1. Time required for convergent throughput: time in milliseconds for throughput to be ≥ the number of data packets generated per second.
2. Average latency: average latency of throughput.

where throughput refers to the number of data packets routed successfully in the past second.

Discussion/Conclusion

We ran our simulations in ideal conditions for OSPF so that we can gauge the maximum possible performance in a particular network. Rather than comparing EACO to OSPF, our main goal was to establish that EACO is indeed an improvement to AntNet and is a feasible option as a routing algorithm.

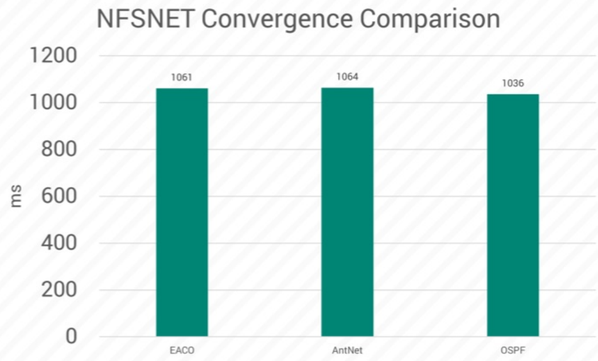
As demonstrated, EACO offers better worst-case and average-case performance than AntNet in terms of adaptation time as well as average latency of throughput.

Future Work

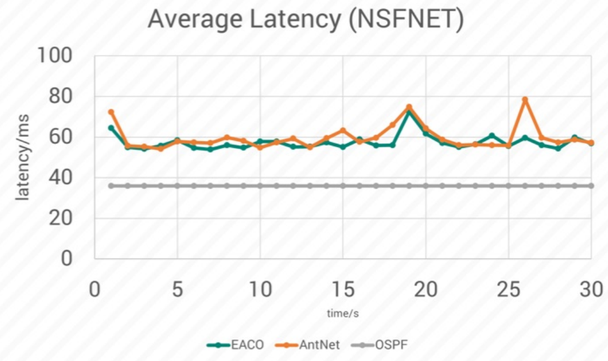
1. Evaluation of different local heuristics (e.g. distance of neighbour to destination)
2. Implementation of faster algorithms that evaluate viability



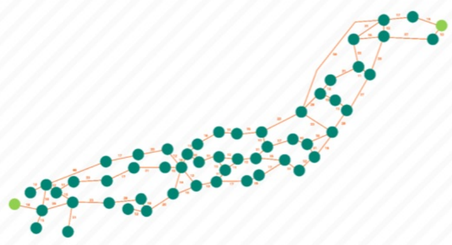
NFSNET, a graph with 0 articulation points
Traffic: 1.5 Mbps
Bandwidth: 1.5 Mbps



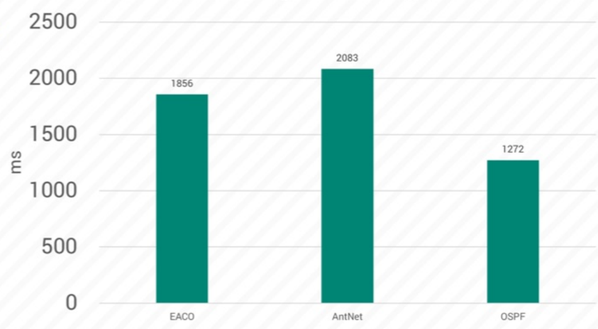
EACO/AntNet have comparable performance in this well-balanced graph



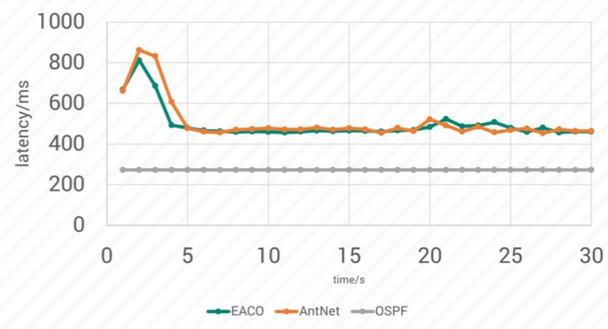
EACO/AntNet latencies average roughly 20ms more than OSPF



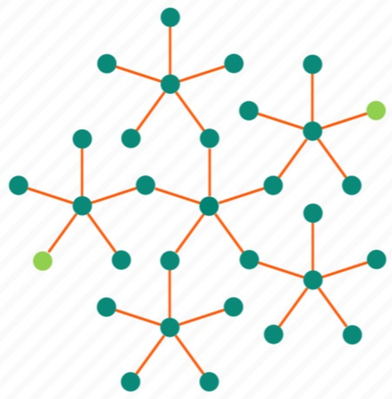
NTTnet, a graph with 4 articulation points
Traffic: 6.0 Mbps
Bandwidth: 6.0 Mbps



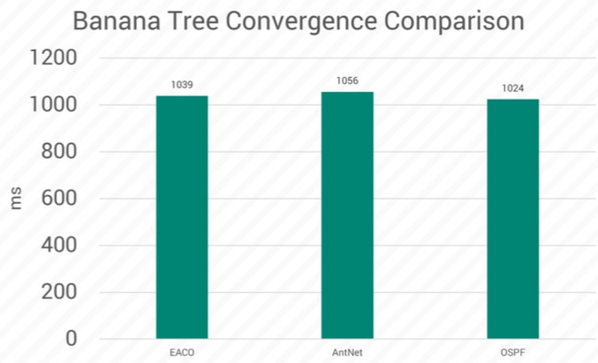
EACO has better performance than AntNet in this poorly-balanced graph



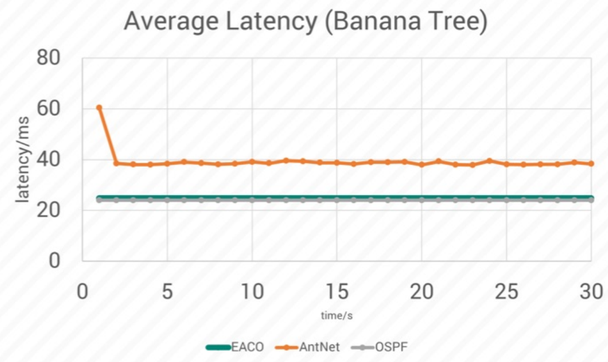
EACO's latency decreases more quickly



Banana Tree, a graph with 11 articulation points
Traffic: 1.5 Mbps
Bandwidth: 3.0 Mbps
Propagation delay of all links are 1ms



EACO has better performance than AntNet, comparable to OSPF



EACO has lower latency than AntNet, comparable to OSPF

References
[1] Gianni Di Caro and Marco Dorigo. 1998. AntNet: distributed stigmergic control for communications network. Journal of Artificial Intelligence Research 9(1): 317-365.
[2] Gianni Di Caro. 2004. Ant Colony Optimisation and its Applications to Adaptive Routing in Telecommunication Networks (Unpublished doctoral dissertation). Université Libre de Bruxelles, Brussels, Belgium.

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All diagrams and graphs were self-drawn.