

Multi-Metaheuristic optimization algorithms for an effective routing system

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Abstract

One of the predominant problems that require great attention in the packet-switch network is finding the optimal routing path for packets movement. The problem leads to an increase in the size of the network, thereby making routing of the network becomes more difficult due to traffic congestion, delay, and time at which packets are delivered over the network. Hence, there is a need to develop an effective routing algorithm that can reduce congestion and time of packet delivery when transferring data over network nodes. This paper applied multi-meta-heuristic optimization algorithms to develop an enhanced routing system by application of three combined nature inspired metaheuristic algorithms; Ant Colony Optimization (ACO), Bat Algorithm, and Tabu Search to reduce the routing problems. Experimental results showed that the developed multi-metaheuristic routing system performed efficiently with 0.002E14s of delay time against the shortest time, 70MB packet size passed through the highest path and 9.4E14 s average delay time against the packet size.

Keywords: ant colony optimization, metaheuristic, network communication, packet-switched network, congestion, multi-metaheuristic

1. Introduction

A significant process in a communication network platform is a routing system^[1]. The process takes into consideration the route selection for traffic in a network or through numerous networks^[2]. Many different types of networks made use of routing which includes circuit-switched networks like the public switched telephone network (PSTN) and networks such as the internet for connection in government and private establishments. Routing is the most highly rated level for making a decision which performs packets transmission from a source towards destination using intermediate network nodes by specific mechanisms for packet forwarding^[3].

An important phase of a computer network is routing protocol in which the selection of a relevant path for transmission of a packet is obtained^[4]. Researchers have applied many algorithms to find the shortest path. The main objective of every network routing is to maximise the network performance by directing the traffic from the source to the destination^[5]. In a network, the performance of the routing process, the bits delivered per unit time (throughput), and the total packets arriving at destination are taken into consideration. In ACO, a mobile agent which is the ant can provide solutions to different problems of network congestion by constant modification of routing tables with respect to congestion.

Lately, techniques using ants have been employed to handle routing problems such as vehicle routing problem, quadratic assignment problem, travelling salesman problem, connection-oriented/ connectionless routing, sequential ordering, graph colouring and shortest common super sequence^[6]. The new optimization algorithms are generally nature-inspired, typically based on swarm intelligence. ACO

is an algorithm which is motivated by the activity of the natural ants in locating the shortest path when foraging for food^[7].

It has been identified that during movement, ants in their colony drop a specific quantity of chemical substance referred to as pheromone in its path while moving from its nest to the food source^[8]. Also when coming back, the ants are constrained to take a similar route noticeable with the chemical substance deposit and again drop the substance in its path. In this pattern, the ants taking the shorter route are supposed to return quickly and hence increase the pheromone volume in its path at a faster rate than the ants passing through a longer path.

The paper applied ACO a meta-heuristics to reduce the problem of network routing due to packet loss and time-taken. Ant Colony Optimization was introduced to locate the optimal path to be followed by a packet in a network.

2. Related Work

Habboush^[9] attempted to give a review of the routing problem in Mobile Ad-hoc Networks (MANET). The main focus was on the use of the ACO technique for the provision of a solution to routing problems in MANET and the discovery routing process at the communication initiation between two nodes in the network. As it was noted that in almost all proposals, FANTs and BANTs were used for the discovery of route and the process is similar in all proposed protocols with little changes across them. However, all solutions converged to a perception that the ACO technique could be one of the highly effective approaches for solving problems related to the discovery of route during communications in MANET between two nodes.

Ravikiran and Dethe^[10] compared several parameters for

the improvement of three different routing algorithms. The study commenced using Low Energy Adaptive Cluster Hierarchy (LEACH) which is a famed clustering mechanism that selected a CH based on the probability model. The system described a fuzzy logic system that initiated the CH selection algorithm for LEACH. Artificial Bee Colony (ABC). ABC was employed to optimize the rule selection. The ABC combined with the fuzzy rule selection technique enhanced the lifetime of the network. Results compared with existing routing algorithms revealed that the proposed technique improved the lifespan of a network as well as a reduction in end to end delays and rate of packet loss.

Sharma and Kushwah [11] developed a system using ACO in wireless sensor network routing for energy saving. Several optimization methods such as Weighted Compressive Data Aggregation (WCDA), Cluster-based Weighted Compressive Data Aggregation (WCDA) & Ant Colony Optimization (ACO). WCDA & CWCDA were analyzed. The WCDA and CWCDA algorithm was used for energy consumption reduction in the WSN model. The simulated results of WCDA and CWCDA were taken based on the sum of energy, percentage of dead nodes and packets send to base station nodes. Problems of WCDA and CWCDA algorithms were discussed and the necessary solution was proposed.

Oloduowo, Akande and Aruleba [12] used an artificial intelligence optimization algorithm called ACO to determine the routing paths in a network and the best route in case of congestion to solve these problems. The ACO approach was improved to provide effective output. The simulation of the system was done in a Visual Basic.Net 2012 (VB 11.0) environment.

Results showed that the developed system allowed activation of a new route if there is time out, congestion or problem in the previous route.

Arkadii and Vadym [13] used the information security risk parameters in the formula of the EIGRP protocol metric calculation to route the traffic by the most secure paths in the network. The method proposed to calculate the risk based on two risk parameters: the risk, which was calculated to the basis of the NIST CVSS standard and the risk calculated based on the formula for the vulnerability of node's degree from the theory of information systems survivability.

The modified algorithm of load balancing between paths that let to offload the most efficient routing node while the network is under the denial of service (DoS) attack was proposed. The results showed that the approach can be used to increase the chance of prevention of the information security violation of routed packets and to keep safe the most efficient routing nodes in the network that allow efficiently routing the trusted traffic while the network is under DoS attack or lack critical system resources.

Khoshkangini and Zabolic [14] used the combination of ACO

and Breadth-First Search (BFS) to obtain the shortest and best route to improve data transmission with reduced energy consumption, as well as a decrease in the chance of loss of data.

The approach balanced up several packets, time and energy consumption to determine which one lead to an increase in network performance. The experimental result showed a reduction in consumption of energy which led to a high lifetime of network and improvement in the amount of data transmission.

3. Methodology

The developed routing system involved the improvement of the routing process in a packet-switch network using multi-metaheuristic algorithms which are nature-inspired computational intelligence optimization algorithms; ACO; Bat optimization algorithm and Tabu search. In the first phase of the study, an ACO based method was introduced to solve network major routing problems which is the challenge of locating the shortest distance for packets movement in a network. To overcome some challenges such as congestion and time-taken by packets in an ACO-based system in reaching their destinations, a nature-inspired optimization algorithm based on the social behaviour of natural bats (BAT algorithm) was applied at the second stage to further enhance the performance of the first nature-inspired computational optimization algorithm, while tabu search list was used to create routing table list to stop cycling process of packets (ants). The system was implemented in Java using Netbeans IDE V7.6 environment. All experiments were carried out using the aforementioned tool and results were analyzed.

3.1 Dataset Acquisition

The primary data used for the performance evaluation of the enhanced routing system of the packet-switched network was obtained from the Network Operation Center (NOC) unit of the University of Ilorin, Ilorin, Nigeria. The data was collected over 12 months. The university network is composed of six routing stages connected in a ring topology to form a complete network where each node in the network is connected to all other nodes forming a ring structure and is as shown in Table 1.

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Table 1: Dataset of University of Ilorin Network

AGRIC - NOC									
S/NC	PACKET SIZE	TTL	AVG-RTT	MAX-RTT (p _i	MIN - RTT	FIRST RTT(St _i	TRANSMISSION	PACKET DELIVERY TIME	
1	56	64	2.33333333	5	1	1	4	0.25	
2	64	64	5	13	1	1	12	0.08333333	
3	70	64	7.33333333	15	2	5	10	0.1	
4	100	64	12.33333333	29	5	3	26	0.038461538	
5	200	64	17	36	7	8	28	0.035714286	
NOC - SENATE									
S/NC	PACKET SIZE	TTL	AVG-RTT	MAX-RTT (p _i	MIN - RTT	FIRST RTT(St _i	TRANSMISSION	PACKET DELIVERY TIME	
1	56	64	11.66	16	8	11	5	0.2	
2	64	64	17.66	19	13	21	-2	-0.5	
3	70	64	20.66	28	23	11	17	0.058823529	
4	100	64	27.66	43	31	9	34	0.029411765	
5	200	64	77.66	170	46	17	153	0.006535948	
SENATE - HKE									
S/NC	PACKET SIZE	TTL	AVG-RTT	MAX-RTT (p _i	MIN - RTT	FIRST RTT(St _i	TRANSMISSION	PACKET DELIVERY TIME	
1	56	64	7.66	15	7	1	14	0.071428571	
2	64	64	9.33	23	4	1	22	0.045454545	
3	70	64	15	35	9	1	34	0.029411765	
4	100	64	16	37	11	1	36	0.027777778	
5	200	64	0	0	0	0	0	0	
HKE - LIBRARY									
S/NC	PACKET SIZE	TTL	AVG-RTT	MAX-RTT (p _i	MIN - RTT	FIRST RTT(St _i	TRANSMISSION	PACKET DELIVERY TIME	
1	56	64	5.33333333	12	3	1	11	0.090909091	
2	64	64	8.33333333	17	7	1	16	0.0625	
3	70	64	14.33333333	29	11	3	26	0.038461538	
4	100	64	12.33333333	36	0	1	35	0.028571429	
5	200	64	0.33333333	0	0	1	-1	-1	
LIBRARY TO OS									
S/NC	PACKET SIZE	TTL	AVG-RTT	MAX-RTT (p _i	MIN - RTT	FIRST RTT(St _i	TRANSMISSION	PACKET DELIVERY TIME	
1	56	64	4.33	9	3	1	8	0.125	
2	64	64	5	11	2	2	9	0.111111111	
3	70	64	4	9	2	1	8	0.125	
4	100	64	6.33	16	2	1	15	0.066666667	
5	200	64	0.66	0	0	2	-2	-0.5	

3.2 Representation of Node Information

The representation of the node information list is the key part of the routing algorithm, which is the reference of the node to select the next hop. Assuming that there are n nodes in the network, then the entire routing algorithm is to maintain an $n \times n$ matrix list, each point in the list, such as node $\langle i, j \rangle$, stores the information between the node i and node j . Including the forward probability P_{id} and heuristic value I_j between node i and node j . Then, the information list between $\langle i, j \rangle$ can be expressed as $\langle i, j, P_{id}, I_j \rangle$. Therefore, the solution is represented as a linear array with representing the path followed by a packet in a routing decision. Each element of the array is composed of the triple

values (node number, P_{id} value, I_j value). The representation of 6 nodes is shown in Table 2:

Table 2: Representation of 6 Nodes

Node	Location
Node 1	5, 0.6, 0.7
Node 2	2, 0.5, 0.6
Node 3	6, 0.7, 1.0
Node 4	3, 0.6, 0.9
Node 5	4, 0.5, 0.3
Node 6	1, 0.6, 0.4

3.3 Node Labels

This study labelled each node of the network for proper presentation and analysis as shown in Table 3.

Table 3: Node Labels

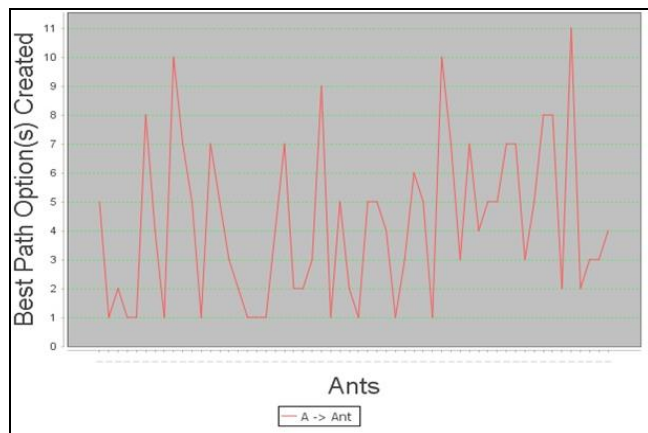
Node Name	Label
Cis	1
Agric	2
Noc	3
Senate	4
Library	5
Hke	6

4. Results and Discussion

The Bat algorithm was employed to decongest the traffic problem initiated by ant colony optimization for various packet sizes.

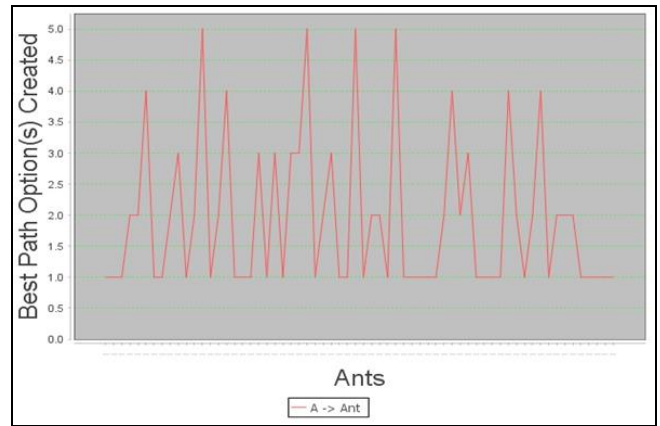
4.1 Results of Combined ACO, Tabu-search and Bat Optimization for 56MB

When the packet size of 75MB was used, the results for the delay against shortest paths and average against shortest paths calculated: the highest number of the path followed per packet (ant) was obtained in (4->3), (4->2) and (3->4) with an increased delay time of 2.6E15(s). The shortest path followed per each packet (ant) was obtained in (5->3) with a reduced delay time of 0.89E12(s). As presented in Figure 1, the highest path followed per packet (ant) was obtained in (2->5>6->1->4->3->2) with an increased average delay time of 6.3E15(s). The shortest path/fastest followed per each packet (ant) was obtained in (4->1->6>5->3->2->4) with a reduced average delay time of 7.4E18(s).

**Fig 1: Best Path Option Vs Ants for 56MB**

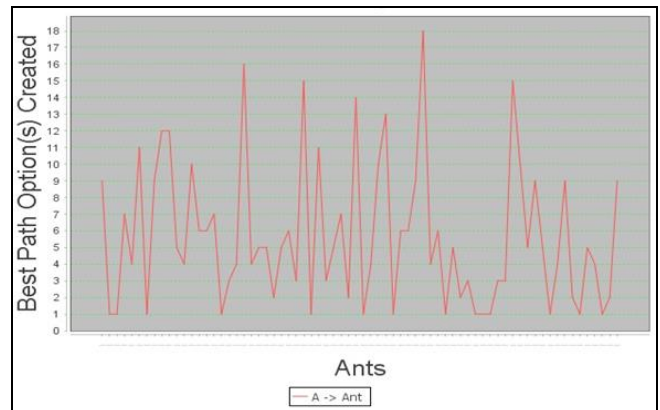
4.2 Result of ACO, Tabu-search and Bat Optimization for 64MB

With a packet size of 64MB, the results were obtained for the delay, average delay and best path option. The highest path followed per packet (ant) was obtained in (3->4), (4->2), (4->3) with an increased delay time of 2.7E15(s). The shortest path followed per each packet (ant) was obtained in (2->1) with a reduced delay time of 0.62E18(s). From Figure 2, the packet size of 13 MB, 26MB, 32MB and 37MB passed through the highest paths/routes of 5, while the lowest number path of 1 path was passed through the following packet size (1, 2, 3, 7, 8, 11, 14, 17, 19, 21, 23, 27, 30, 31, 33, 36, 38, 39, 40, 41, 42, 47, 48, 49, 50, 53, 56, 60, 61, 62, 63, 64)MB.

**Fig 2: Best Path Option Vs Ants for 64MB**

4.3 Result of ACO, Tabu-Search and Bat Optimization for 70MB

With a packet size of 70MB, the results for the delay, average delay and best path option. The highest path followed per packet (ant) was obtained in (4->4), (4->1), (3->4) with an increased delay time of 2.7E15(s) as presented in Figure 8. The shortest path followed per each packet (ant) was obtained in (4->2) and 2->1 with a reduced delay time of 0.6E14(s). In Figure 3, the packet size of 44 MB passed through the highest paths/routes of 18 to reach its destination, while the lowest number of 1 path was passed through the following packet size (2, 3, 7, 17, 29, 36, 40, 47, 51, 52, 53, 61, 65, and 68) in MB.

**Fig 3: Best Path Option Vs Ants for 70MB**

4.4 Result of Combined ACO, Tabu-search and Bat Optimization Using 100MB

With a packet size of 100MB, the results obtained for the delay against the shortest path and average delay and shortest path option were created.

The shortest path followed per each packet (ant) was obtained in (6->5) with a reduced delay time of 0.002E14(s).

As presented in Figure 4, packet size of 6 MB, 21MB, 35MB passed through the highest paths/routes of 9 to reach its destination, while the lowest number of 1 path was passed through the following packet size (1, 4, 5, 9, 11, 12, 16, 22, 25, 26, 28, 30, 37, 39, 41, 42, 44, 51, 54, 55, 56, 57, 72, 73, 74, 78, 79, 84, 85, 90, 92, 95, 100) in MB.

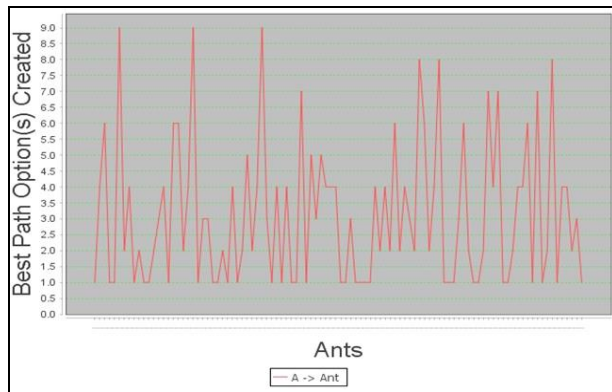


Fig 4: Best Path Option vs Ants for 100MB

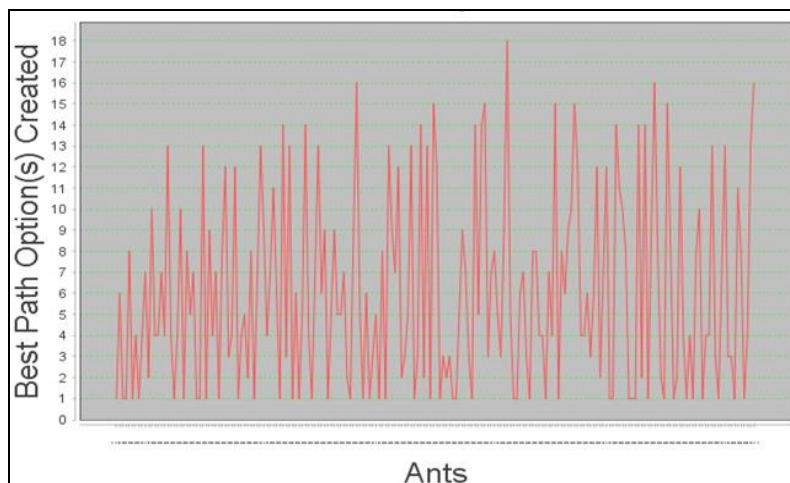


Fig 5: Ants Vs Best Path Option for 200MB

The results for the average delay and packet size computed for all the packet sizes used are shown in Figure 6. The packet size of 100MB gave the lowest average delay time of $9.4E14(s)$, while 70MB gave the highest average delay time of $11E15(s)$. The overall output of average delay time against packet size showed that the 100MB packet size produced the best average delay out of other packet sizes.

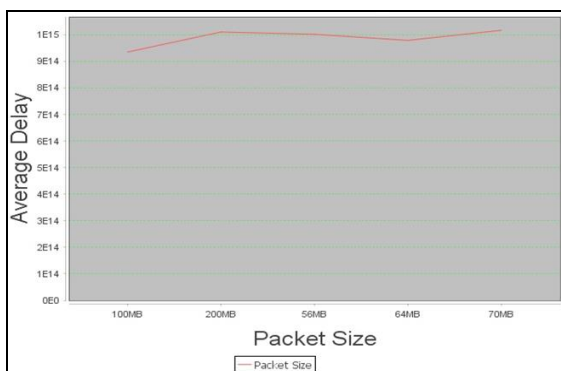


Fig 6: Average Delay Time Vs Packet Size

5. Conclusion

A nature-inspired based optimization techniques have been applied by researchers in solving hard combinatorial problems such as routing, travel salesman problems, graphs and so on. This study applied multi-metaheuristic optimization algorithms to reduce the routing problem in the switch-packet network. ACO was introduced as a defacto algorithm to find the shortest path, while the bat algorithm

When a packet size of 200MB was used, the results for the delay and best path option calculated. The highest path followed per packet (ant) was obtained in (4->3), (4->2), (3->4) with an increased delay time of $2.7E15(s)$. The shortest /fastest path followed per each packet (ant) was obtained in (2->4) and (2->1) with a reduced delay time of $0.6E16(s)$. As shown in Figure 5, packet size of 123MB passed through the highest paths/routes of 18 to reach its destination, while the lowest number of 1 path was passed through the following packet size (1, 3, 4, 6, 8, 19, 22, 26, 27, 29, 33, 39, 44, 52, 56, 58, 62, 67, 74, 78, 80, 83, 85, 94, 99, 102, 106, 107, 112, 125, 126, 130, 135, 139, 155, 156, 161, 162, 163, 167, 172, 175, 179, 181, 184, 189, 194, 197) in MB.

was used to decongest the traffic problem during the process of choosing the shortest route. Recycling of the packet was stopped through a tabu search approach. The University of Ilorin network system platform was used to evaluate the performance of the developed Multi-metaheuristic optimization algorithm for an enhanced routing system. Different results in terms of delay against the shortest path, average delay against shortest, best path option and average delay against packet size.

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