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Enhanced Routing System for Packet-Switched Network Using Ant Colony Optimization Algorithm

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Abstract - Network communication is a process that involves the technique of routing for delivering the packet by choosing an optimal path from one network to another. One of the major challenges that require attention in network communication is the problem of finding the optimal routing path for packets movement. The problem usually arises in a packet-switched network as the size of the network increases, thereby making routing becomes more complex due to the number of nodes in the network. Thus there is need to develop a better routing algorithm to provide effective traffic routing system that can update their path by finding the optimal network nodes that will allow effective and fast access to the network within a real-time interval. This paper developed an improved routing system by application of a natured inspired metaheuristic algorithm to reduce the routing congestion problems. Experimental results showed that the shortest path (1-2-3-4) had the lowest average delay time of 2.03s with packet size of 56mb, while the 64mb with the shortest path (1-2-4-5-3-6) gave the lowest path congestion ratio of 43.

***Keywords**: Ant Colony Optimization, Metaheuristic, Network Communication, Packet-Switched Network*

1. Introduction

In a communication network system, routing remains a significant process [1]. This process involves the selection of a path for traffic in a network, between or across multiple networks [2]. Routing is performed for many types of networks including circuit-switched networks, such as the public switched telephone network (PSTN), computer networks, such as the internet as well as in networks used in public and private transportation. Routing is a higher-level decision making that directs network packets from their source toward their destination through intermediate network nodes by specific packet forwarding mechanisms [3]. Routing protocol performs an important part in computing, selecting and choosing a relevant path for transferring data from the source to the destination efficiently [4]. Several routing algorithms have been employed to locate the shortest path and also to increase the throughput of the network system. The major purpose of every network routing algorithm is to direct the traffic from source to the destination maximizing the network performance [5].

The performance measurement of a communication network is usually taken into consideration during routing, the throughput (bits delivered per unit time) and several packets successfully reaching the destination. In Ant Colony Optimization, an ant is a mobile agent that is capable of solving various kinds of routing and congestion problems in computer networking by continuously modifying routing tables in response to congestion. In recent years, ant-based algorithms were used to solve classical routing problems such as travelling salesman problem, vehicle routing problem, quadratic assignment problem, connection-oriented/ connectionless routing, sequential ordering, graph colouring and shortest common super sequence [6].

Modern optimization algorithms are often nature-inspired, typically based on swarm intelligence. Ant colony optimization (ACO) is an algorithm based on the behaviour of the real ants in finding the shortest path from a source to the food [7]. This algorithm utilizes the behaviour of real ants while searching for food. It has been observed that the ants deposit a certain amount of pheromone in its path while travelling from its nest to the food [8]. Again while returning, the ants are subjected to follow the same path marked by the pheromone deposit and again deposit the pheromone in its path. In this way, the ants following the shorter path are expected to return earlier and hence increase the amount of pheromone deposit in its path at a faster rate than the ants following a longer path.

This paper applied ACO to find the optimal shortest path solutions to the problem based on the model and representation defined.

2 Related Work

[9] attempted to give a summary of contributions available for addressing the problem of routing in Mobile Ad-hoc N*etworks* MANET. The main focus was on the use of ACO technique for the resolution of routing issues in MANET and in particular the route discovery process at the beginning of communication between two nodes in the network. As it can be observed that in almost all proposals, FANTs and BANTs are used for route discovery and the process followed is the same across all proposed protocols with a few variations across them. However, all solution converges to a perception that the ACO technique could be one of the most efficient mechanisms for resolving issues related to route discovery during communications between two nodes in MANET.
[10] compared improvements in various parameters for three different routing algorithms. First, the study started with Low Energy Adaptive Cluster Hierarchy (LEACH) which is a famed clustering mechanism that elected a CH based on the probability model. The study described a fuzzy logic system initiated the CH selection algorithm for LEACH. Artificial Bee Colony (ABC) which is an optimization protocol owes its inspiration to the exploration behaviour of honey bees. ABC was utilized to optimize the rule selection. The ABC optimization with fuzzy rule selection approach is given for improving the network lifetime. The experimental results compared with other routing algorithms proved that the suggested method enhanced the network's lifespan as well as reduced the delay from end to end delays and rate of packet loss in comparison with other selection methods.

[11] presented a study on ACO-based wireless sensor network routing for energy saving. The study employed optimization techniques such as Weighted Compressive Data Aggregation (WCDA), Cluster-based Weighted Compressive Data Aggregation (WCDA) & Ant Colony Optimization (ACO). WCDA & CWCDA are analyzed and discussed. WCDA & CWCDA algorithm was used for reducing energy consumption in WSN model. The simulation results of WCDA & CWCDA algorithms were illustrated in terms of the sum of energy, percentage of dead nodes and packets send to base station nodes. Issues of WCDA & CWCDA algorithms were mentioned and a required solution was proposed. Final simulation results of WCDA & CWCDA showed consumption of energy was minimized as compared to other methods.

[12] used the parameter of information security risk 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 degree of node vulnerability 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 through the trusted traffic while the network is under DoS attack or lack critical system resources.

[13] came up with an Ant Colony Optimization (ACO) combined with Breadth-First Search (BFS) to search and find the best and shortest path to improve data transmission with the least amount of energy consumption, as well as reduce the probability of data loss. The method set a balance between the number of packets, time and energy consumption can be determined which led to increasing the network performance. The main goal of the study was to reduce energy consumption which resulted to increase of the network's lifetime and enhancement of the number of successfully transmitted data concerning other multiple ants- based routing protocols.

3. Methodology

The developed routing system involved the reduction of routing problem in a communication network system using nature-inspired computational intelligence optimization algorithms; Ant Colony Optimization. ACO based method was introduced to solve network major routing problem which is the challenge of locating the shortest distance for packets movement in a packet-switch network. 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.

				AGRIC - NOC				
S/NC	PACKET SIZE	TTL	AVG-RTT	MAX-RTT (pa	MIN - RTT	FIRST RTT(St	TRANS TIME	PACKET DELIVERY TIME
1	56	64	2.33333333	5	1	1	4	0.25
2	64	64	5	13	1	1	12	0.083333333
3	70	64	7.33333333	15	2	5	10	0.1
4	100	64	12.3333333	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 (pa	MIN - RTT	FIRST RTT(St	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 (pa	MIN - RTT	FIRST RTT(St	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 (pa	MIN - RTT	FIRST RTT(St	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	14.3333333	29	11	3	26	0.038461538
4	100	64	12.3333333	36	0	1	35	0.028571429
5	200	64	0.33333333	0	0	1	-1	-1
				LIBRARY TO CIS				
S/NC	PACKET SIZE	TTL	AVG-RTT	MAX-RTT (pa	MIN - RTT	FIRST RTT(St	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

Table 1: Dataset of University of Ilorin Network

3.2 Representation of Node Information

The representation of 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 a n * n matrix list, each point in the list, such as node <i, j>, 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 <i, j> can be expressed as <i, J, P_{id} , I_j >. 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

4.1 Experimental Results

Results of the enhanced routing system were presented in terms of shortest path and average delay based on the packet size as shown in Table 4 and Table 5.

Table 4: Shortest path generated by ACO on all packet sizes

SHORTEST PATH				
56MB	**64MB**	**70MB**	**100MB**	**200MB**
1-3-2-3-4-5-6	1-5-4-2-3-6	1-2-3-4-5-6	1-3-2-4-5-6	1-3-2-4-5-6
1-2-3-4-5-6	1-2-4-5-3-6	1-5-2-4-3-6	1-5-3-2-4-6	1-5-2-3-4-6
1-5-2-3-4-6	1-2-5-3-4-6		1-5-2-3-4-6	

Table 5: Average delay of a shortest path generated by ACO on all packet sizes

AVERAGE DELAY TIME (s)				
56MB	**64MB**	**70MB**	**100MB**	**200MB**
2.82364249	3.00229161	2.02564249	4.0656980	4.34313446
3.56185883	3.80810737	4.12916868	4.13568407	4.68527495
3.15414011	3.66838991		4.42681849	

4.2 Comparative Analysis of Shortest Path with Average Delay Time

From the results, it can be seen that ACO was able to find 3 shortest paths for 56 mb packet size, 3 shortest paths for 64 mb packet size, 2 shortest paths for 70 mb packet size, 3 shortest paths for 100 mb packet size and 2 shortest paths for 200 mb. Furthermore, path **1-3-2-4-5-6** had the lowest delay in three of the packet size: approximately 2.83s with 56mb packet size, 4.07s with 100 mb packet size and 4.34s with 200mb packet size. Figure 1 presents the average delay of all the optimal paths generated by the algorithm. It can be observed that the lowest average delay time of (2.03s) was obtained in paths wi **1-2-3-4-5-6** and path **1-5-2-3-4-6** recorded the highest average delay time of (4.69s).

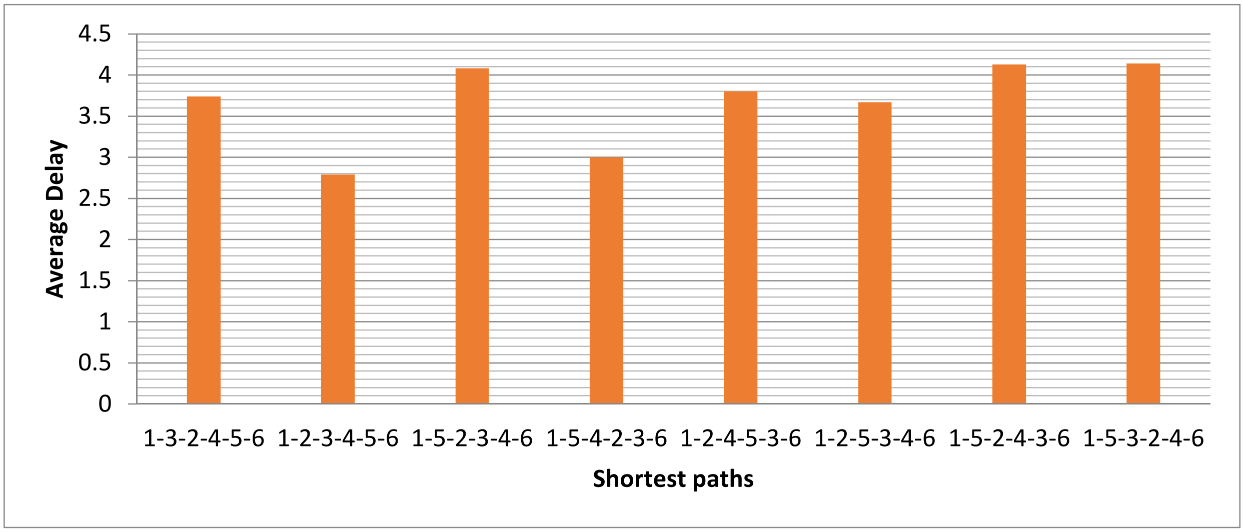

Figure 1 Average Delay of all the Shortest Paths

It can as well be observed that as the packet size increases, the delay in the network increases except for 70mb where there is a sharp decrease in delay. Figure 2 also shows the graph of the packet size plot against average delay which explicitly reveals this relationship. The increase in delay slightly affects the shortest path as the best shortest path from 56 mb size to 200 mb size changes with the increase except from 100mb to 200mb where the shortest path is retained. The algorithm was able to generate applicable results given the appropriate size of a packet. To further analyze the performance of the ACO algorithm, the congestion rate of each node of the optimal results from ACO were measured. The congestion rate of each node is calculated as the sum of all paths in the solution that passes through the node as given in Equation (1):

$$C_R = \sum_i^N P_i \qquad (1)$$

Where C_R is the Congestion ratio, P_i is the number of paths containing the i^{th} node in the solution space and N is the population size.

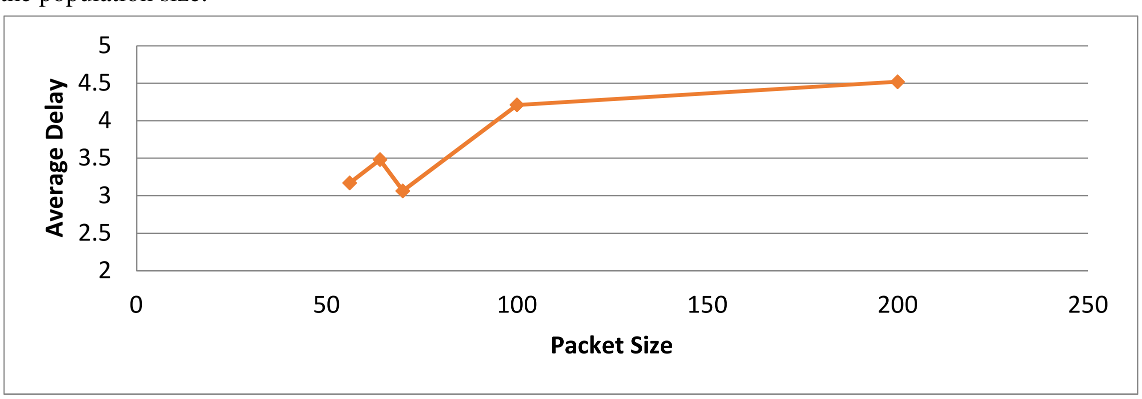

Figure 2: Packet size against average delay

The results of the congestion rate of each optimal path generated by ACO based on the various packet sizes are given in the following Tables

Table 6: Congestion ratio of each path on packet sizes for 56 MB

56 MB		
Shortest Path	**Congestion in Node**	**Path Congestion**
1-3-2-4-5-6	9 61 21 5	96
1-2-3-4-5-6	2 64 11 5	82
1-5-2-3-4-6	3 17 21 11	52

Table 7: Congestion ratio of each path on packet sizes for 64 MB

64 MB		
Shortest Path	**Congestion in Node**	**Path Congestion**
1-5-4-2-3-6	7 77 10 1	96
1-2-4-5-3-6	5 12 21 19	43
1-2-5-3-4-6	5 7 25 20	57

Table 8: Congestion ratio of each path on packet sizes for 70 MB

70 MB		
Shortest Path	**Congestion in Node**	**Path Congestion**
1-2-3-4-5-6	6 51 21 6	84
1-5-2-4-3-6	2 34 11 5	52

Table 9: Congestion ratio of each path on packet sizes for 100 MB

100 MB		
Shortest Path	**Congestion in Node**	**Path Congestion**
1-3-2-4-5-6	6 41 2 9	58
1-5-3-2-4-6	5 12 12 19	48
1-5-2-3-4-6	3 77 10 9	99

Table 10: Congestion ratio of each path on packet sizes for 200 MB

200 MB		
Shortest Path	**Congestion in Node**	**Path Congestion**
1-3-2-4-5-6	3 52 10 6	74
1-5-2-3-4-6	3 22 3 17	45

From the results, it was observed in Table 9, that the path 1-5-2-3-4-6 (the path with the lowest average delay) has the highest maximum congestion value of 99, the path 1-2-4-5-3-6 has the lowest maximum congestion value of 43 and the path 1-5-2-3-4-6 (the path with the highest average delay) has second to the lowest maximum congestion value of 45. Figure 18 presents the maximum congestion values of each path.

Figure 3: Maximum Congestion values of the shortest paths

So it can be inferred that the path with the lowest delay is having the highest congestion rate. This can be traced back to the fact that the ACO algorithm will try to suggest the same path for both forward agent and backward agent and most packets tend to follow the optimal shortest path. Therefore, there is a need for another technique to balance the congestion rate with the delay.

5. Conclusion

This study applied the Ant Colony Optimization Algorithm to reduce the routing problem of finding the optimal path in a switch-packet network system. The data used was gathered from the University of Ilorin network system platform. The collected data was used to evaluate the performance of the developed enhanced routing system. Experimental results were given in terms of the shortest path generated, congestion rate and maximum congestion values of the shortest paths.

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