Minimization of Handoff Failure in a Heterogeneous Network Environment using Multi Criteria Fuzzy System

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***Abstract*— Handoff is an important aspect in the design of wireless communication that fulfills one of the major requirements for continued call connectivity as mobile traverses' different wireless networks. One major challenge in heterogeneous network environment is vertical handoff, which relies on efficient decision making and fast selection strategy to reduce unnecessary handoff and failures. To achieve this goal, we propose the use of artificial intelligence-based techniques, Fuzzy Logic and Artificial Bee Colony (ABC) to decide when and where handoff would be initiated and an algorithm to select the best available network to the user. This approach relied on several parameters, the decision stage adopted network parameters such as RSSI, RSRQ and Throughput. While QoS parameters Bandwidth, Latency, Snr, Throughput, Cost and power were adopted for the selection stage. The simulation was carried out in two different stages using Matlab. The result showed decision was made at -80 dBm for RSSI, Throughput at 0.05Mbps and RSRQ at -25 dBm. While the output probability was 0.87 (87%). Results from the execution stage showed the selection to the best available network was achieved and the chosen network offered the lowest cost and highest Throughput to the user. Performance evaluation indicated that the number of handoffs was minimized and the execution time of the ABC algorithm showed better performance when compared to the Genetic Algorithm.**

***Index Terms*— Handoff; Heterogeneous Network; Fuzzy Logic; Artificial Bee Colony**

I. INTRODUCTION

At present, the level of technological advancement experienced in the telecommunication sector is quite applauding. The services offered by wireless networks are rapidly growing, and they are available to satisfy the demands of mobile users [1]. The existence of varying wireless networks has gradually led wireless networks to become heterogeneous in nature, thus providing a variety of new applications that eases the transition across multiple wireless network interfaces [2].

Heterogeneous networks represent an emerging trend in wireless technology, one that offers wireless network operators the ability to exploit advantages of different access networks to solve problems related to limited capacity in existing wireless systems. This is made possible by the presence of different access points (APs) representing different radio access technologies (RATs) such as LTE, 3G, WiFi, and WiMAX [3].

Handoff is a major challenge in environments with Heterogeneous Networks. In a Heterogeneous network environment, handoff is vertical and becomes more demanding as the mobile user needs to transfer service to a preferred network from a different network domain and technology such as WiMax, WiFi, UMTS/LTE and others [4]. Handoff decisions depend mostly on different set of parameters such as Network related, terminal related, user related and service related [2], as shown in Table 1.

The vertical handoff processes consist of three phases: discovery, decision and execution. Eventually, the available network links are introduced using the accumulated information on factors including the throughput, handover rate, cost, location, packet loss ratio, received signal strength (RSS), carrier interference ratio, signal-to-interference and noise ratio (SINR), bit error rate and QoS parameters of the discovery stage [5].

Table 1
Decision Parameters for Handoff

Parameter Group	Variable
Network	Bandwidth, Latency, RSS, SIR, Cost, Security
User	User Profile and Preferences, service capacities QOS
Terminal	Velocity, Battery Power, Location Information

The problems experienced in heterogeneous handoff are related to decision making and network selection. The decision-making process needs to identify when and where to initiate handoff, while the selection process needs to utilize an efficient algorithm to select a network with guaranteed quality of service within a limited time. Recent researches have suggested few approaches that give directional assistance in selecting a candidate network during the handoff process. However, it has become essential to offer an efficient handover mechanism to meet different QoS requirements and maximize the resource utilization of the network.

In this paper, we propose an adaptive multi-attribute vertical handoff decision algorithm based on artificial intelligence technique to handle the decision making and network selection during the handoff process.

A. Related Works

Different strategies have been adopted to solve the problems associated with vertical handoff. In this work, we will review literatures related to handoff decision and network selection.

B. Handoff Decision Based Techniques

[2] used a multi criteria vertical handoff decision algorithm. Their work was designed to select the best available network with optimized parameter values (such as cost of network should be minimum) in the heterogeneous wireless network. They formulated the decision problem as a multiple objective optimization problem and implemented the simulation using genetic algorithm. The simulation result showed that the number of handoff was less when all parameters were optimized.

[6] developed a fuzzy logic-based controller to reduce the number of unnecessary handoffs. With the advantage of feedback technology, this controller dealt with the impact of indeterminable changes in the Received Signal Strength (RSS) as the user changed position. This controller helped to take an accurate decision only when handoff is needed. Simulation results revealed that the proposed controller reduced handoff probability and number of unnecessary handoff.

In [7], the authors developed handoff algorithm, implemented using fuzzy logic. Parameters such as RSS, monetary cost, bandwidth, time delay and BER were used. AODV was used as a routing protocol for transmission of packets. The simulation results showed that the proposed scheme performed better, reduced unnecessary handoff compared to the sole Fuzzy Logic based algorithm and eliminates the serious ping-pong effect.

[8] used a rule-based handover decision scheme based on Fuzzy. The work was aimed at developing a system to select the best network amongst WLAN, WWAN and Cellular network, and determine the necessity of handoff. A combination of network parameters such as RSS, bandwidth, user preference, MS-velocity, MSAP distance, delay, cost, security and number of users were chosen. The proposed scheme was simulated in MATLAB using SIMULINK model and fuzzy based system designed in fuzzy logic toolbox. In this work, only 27 rules were used instead of 39 rules that were needed for 9 attributes to determine the value of the final vertical handoff factor (VHO) for all the three networks. Results showed that the use of large number of attributes improved the handoff decision in heterogeneous networks. It also resulted in lesser number of unnecessary handoff as compared to traditional fuzzy.

[9] carried out a study on the interoperability between WiFi and WiMax in Hetnets environment. This work aimed to solve the problem of identifying a point when a user must move from one network to another network. Handover decision mechanism in an integrated WiFi-WiMax scenario was proposed, and this could support QoS and QoE of the end users. Bandwidth management and admission control scheme were chosen for proper distribution of the total traffic in the network over the integrated WiFi-WiMax environment, with QoS. They achieved a class aware load balancing and context aware handover policy which could help in decreasing delay and connection drop probability.

[10] developed a handover system using Wi-Fi and WiMaX in heterogeneous networks. An OMNET simulator was used to determine the performance of parameters such as Delay, packet loss and throughput of GSM, WiFi and WiMax. This work achieved an algorithm which supported the best access point for horizontal handover decisions and vertical handover decisions to user based on the current set of user preference, application requirements, and context information.

[11] developed an Adaptive Network Based Fuzzy Inference System. This model was used to minimize handoff failure in mobile networks. They adopted parameters as Signal to interference ratio, speed of the mobile users and traffic distance, which were the three inputs used in the Adaptive network based Fuzzy inference system (ANFIS). The hybrid of two artificial intelligence techniques made it suitable to handle complexities such as ping-pong effect and interference which impaired the quality of service (QoS) during call handover process.

[12] adopted a multi criteria approach in their work to develop an improved algorithm for handoff decision. The proposed algorithm had three vertical handoff decision algorithms namely: mobile weight, network weight, and equal weight. Additionally, three network technologies were adopted and embedded in the study which included WiMaX, WLAN, and LTE. The simulation result indicated that the handover decision algorithm for network weight showed exceptional outputs when compared to mobile and equal weights, as well as the conventional network decision algorithm.

C. Network Selection

Reference [13] proposed a heterogeneous model, which was used to analyze the performance of vertical handover, while considering 4G and wireless data networks. The radio link quality and merit function of access network were used to estimate the vertical handoff performance and delay. Results showed that the delay was within the pre-assumed range, hence showed better performance when compared to the existing handover algorithms in terms of delay, service rate and handover dropping probability in heterogeneous networks.

Reference [5] proposed the use of Genetic Algorithm and Simulated Annealing methods for search and optimization problems in heterogeneous wireless networks. This work was aimed at specifically solving two major issues in GA optimization namely premature convergence and slow convergence rate, and the facilitation of simulated annealing in the merging populations phase of the search. Cost function was adopted to sustain the desired QoS in the transition between networks, which is measured in terms of the bandwidth, BER, ABR, SNR, and monetary cost. Simulation results indicated that GSAVHO had a lower cost function compared to the GAVHO. Simulation results indicated that our proposed VHDA was able to minimize the cost function, reduce the number of unnecessary handovers.

D. Genetic Algorithm

Genetic Algorithms (GAs) are adaptive heuristic search method whose operational mechanism relies on evolution and natural genetics (behavior of chromosomes). The basic concept of the GA design is a natural system model processes that requires evolution, specifically following the principles developed by Charles Darwin for the purpose of finding the survival of the fittest. GAs solve problems using intelligent approaches by developing a random search within a defined search space. It adopts the following attributes: (1) There is Competition for space and mates by individuals within a population, (2) The most successful individuals in each competition will produce more offspring than the individuals that perform poorly; (3) Genes from ‘good’ individuals propagate throughout the population so that two good parents will sometimes produce offspring that are better than either parent; and (4) Each successive generation will become more suited to their environment. Although genetic algorithms (GAs) are very popular, they suffer from three main problems.

- The first issue is attributed to premature convergence resulting from high reliance on crossover. This can give impact on the population by making the population more homogeneous, which slows down the search for the best solution at the mutation stage.
- The second problem of genetic algorithms is related to the convergence of the optimal solution after finding a near-optimal solution.
- The third issue is related to the high degree of memory space used by genetic algorithm.

E. Artificial Bee Colony (ABC)

The ABC algorithm was developed using the intelligent foraging attributes of the swarm honeybees. In the ABC algorithm, every cycle consists of three steps: At the beginning, a random selection of food sources is done by bees and their amounts are given. A new food source is produced, and the new nectar amount can be obtained by the new food source. The artificial bees discover randomly a population of initial solution vectors and then iteratively improve them by employing the strategies: moving towards better solutions utilizing a neighbor search mechanism, while abandoning poor solutions. There are three types of bees involved in the search for food source or solutions, namely the employed bees, the onlooker bees, and the scout bees [5]. In an optimization context, the number of solutions in a population is an indication of the number of food sources. Additionally, the position of a promising solution is indicated by the position of the food.

The ABC generates a randomly distributed initial population of s_N solutions (food sources), where s_N denotes the swarm size. Let $X_i = \{x_i, 1, x_i, 2 \ldots . x_i D\}$ represents the i_{th} solution in the swarm, where D is the dimension size. Each employed bee X_i generates a new candidate solution V_i about its present position as follows [14]:

$$\boldsymbol{V_{i,j} = X_{i,j} + \emptyset_{i,j}(X_{i,j} - X_{k,j})} \qquad (1)$$

Assume that the abandoned source is X_i, then the scout bee finds a new food source to be replaced with X_i as follows:

$$\boldsymbol{X_{i,j} = lb_j + rand\ (0, 1) \cdot (ub_j - lb_j)} \qquad (2)$$

Where rand (0, 1) is a random number within (0, 1) based on a normal distribution, and lb, ub are the lower and upper boundaries of the j_{th} dimension, respectively. This probabilistic selection is really a roulette wheel selection mechanism, which is described as follows:

$$\boldsymbol{P_i = \frac{fit_i}{\sum_{j=1}^{s_N} fit_j}} \qquad (3)$$

Where: $\boldsymbol{fit_i}$ is the fitness value of the i_{th} solution in the swarm, the better the solution i, the higher the probability of the i_{th} selected food source.

II. MATERIALS AND METHOD

This work is separated into three modules, as shown in Figure 1. The first module consists of the data capture stage using drive testing approach to capture live data, and the second adopts fuzzy Logic to determine when and where to handoff. The third stage involves the scanning and switching phase to the best available network using the Artificial Bee Colony algorithm. Simulation technique was adopted in this work.

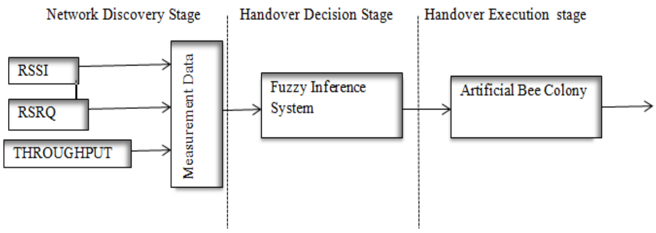

Figure 1: Handoff Approach in LTE

A. Drive Test

Drive Test approach was done to capture relevant signal parameters. The tools used include TEMs Phone (Sony Ericsson W99), 4G Modem, Laptop, Global Positioning System (GPS), TEMS software and a car. This was carried out from Artillery to University of Port Harcourt Campus, Choba.

B. Scenario 1 Decision Stage

The second scenario is designed using the Fuzzy Logic system as shown in Figure 2. Drive test data collected from LTE signal from the environment was fed into the Fuzzy system. Three input variables were chosen namely RSSI, RSRQ, and Throughput as they are the key factors in handoff determination, as shown in Table 2.

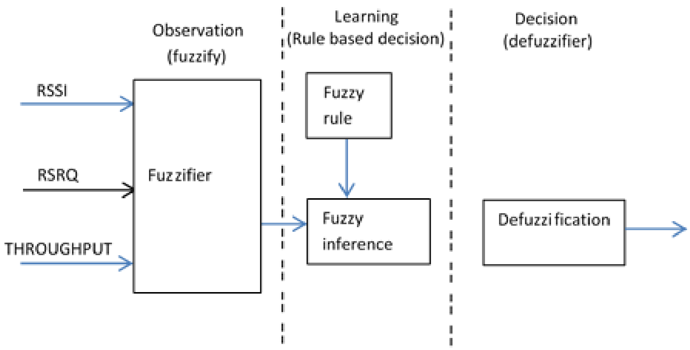

Figure 2: Proposed Fuzzy Logic handoff system

Table 2
Parameters for Handoff decision (scenario 1)

SN	Parameter	Range Min	Range Max
1.	RSSI (dBm)	-90	-49.7
2.	RSRQ (dB)	-27	-5.8
3.	Throughput (kbps)	0	0.25

C. Implementation

In the first step, the Triangular membership function was used to convert fuzzy variables into crisp numbers. The second steps involved the mapping of a set of crisp numbers of imprecise attributes (raw attributes) to the fuzzy set of linguistic descriptions. These crisp numbers are measurement values of the raw attributes and the fuzzy set of linguistic descriptions, which show an acceptable level or relative degree. The linguistic variables are set as RSSI (Poor, Weak, Strong, Very Strong), RSRQ (Bad, Poor, Good, Very Good) and Throughput (Very Low, Low, Good, Very Good), as shown in Table 3. In the third stage, Rules were developed, in which the set of fuzzy rules were made to infer on the scope of the output variables using linguistic descriptions. The if-then rules were applied according to the input variables. The Fuzzy rules are of the form "IF x is A, and y is B, then z is C". Where A, B and C are fuzzy sets. A total of 64 fuzzy rules were generated from knowledge acquisition. In the fourth stage, Defuzzification was done (4). This is an inverse process of the Fuzzification stage, where the output of the Fuzzy reasoning is transformed into a non-Fuzzy number which represents the actual output of the system.

$$f(x) = \frac{\sum \mu(x) \cdot x}{\sum \mu(x)} \quad (4)$$

Where $f(x), x, \mu(x)$ represents the crisp output value, crisp weighting for the linguistic value and membership value of x with relation to the linguistic value [15].

Table 3
Membership Functions for the input Parameters

SN	Fuzzy Variable		Range Min.	Max.
1.	RSSI	Poor	-90.0	-76.57
		Weak	-80.0	-66.0
		Strong	-68.0	-55.0
		Very Strong	-60.0	-50.0
2.	RSRQ	Bad	-27.0	-20.5
		Poor	-20.5	-15.5
		Good	-15.5	– 10.5
		Very Good	-10.5	-5.8
3.	Throughput	Very Low	0	0.070
		Low	0.057	0.135
		High	0.123	0.194
		Very High	0.18	0.25

D. Scenario 2 Handoff stage

This section describes the implementation of an intelligent approach that has the ability to select the best available wireless network.

E. Problem Description

We consider a mobile node moving in an area covered by a set of wireless networks managed by four Network Service Providers (NSP_{i} i=1...4) with varying signal strengths [19]. The mobile device was configured to be in idle mode,while the modem was configured to be an active mode with live download while moving in the environment. With the signal dropping to such a level that requires a transfer of service to sustain the ongoing session, the proposed algorithm will select a target network from the list of available networks in a timely fashion. The network selection process was formulated as an optimization process. Basically, the problem was considered as an optimization problem that can be represented as $Minimize \sum t_i$.

F. Implementation

The work was implemented using an Acer Laptop with Intel Pentium(R) Dual Core T4500 (2.30GHz) and 2GB RAM. The algorithm was implemented with Matlab R2014a software. The simulation parameters for the access networks are shown in Table 4. Each network is identified by using the Quality-of-Service parameter values, as shown [2]:

$$Q = f\{B_i, 1/L_i, 1/SNR_i, TH_i, 1/C_i, 1/P_i\} \quad (5)$$

where B, L, SNR, TH, C, P represent Bandwidth, Latency, Signal to Noise Ratio, Throughput, Cost, and Power respectively. The problem is modeled as an optimization problem aimed at aligning the Quality-of-Service weights to establish a favorable network among the available networks. The efficient adjusting capability of the QoS weights to establish the best network from the available networks is essential in wireless networks. To allow for different circumstances, each factor is attached to a weight, which is related to the magnitude it endows upon for vertical handoff [2], [16], [17] and [18]:

$$Q_i = f\{w_b \times B_i, w_l \times 1/L_i, w_{SNRi} \times 1/SNR, w_{Th} \times TH_{i,} w_c \times 1/C_i, w_p \times 1/P_i\} \quad (6)$$

The weights $w_b, w_l, w_{SNR}, w_{Th}, w_c, w_p$ show the weights for each network and device parameters respectively. The sum of all the attached weights is equal to 1. A specific factor of higher weight indicates how important the factor is to the user. The probability of a food source (wireless networks) in (4) being selected by the onlooker bees increases the fitness value of the food source. The selection algorithm selects the network with minimum cost and maximum throughput. The proposed algorithm for the handoff implementation is demonstrated in algorithm 1.

Algorithm 1
Proposed ABC handoff Algorithm

1: Select the available wireless networks
2: Set ABC parameters, include maximum cycles, bee colony size and limited trail.
3: Initialize ABC food sources randomly (Het-Net1...4).
4: Determine the quality of the food source using fitness calculation.
5: Cycle ← 1
6: While Cycle < Maximum Cycles Do
7: Generate new employed bees (new candidate solutions)
8: Evaluate the new quality of the new solution using fitness calculation
9: Apply greedy selection approach
10: Determine the probability values by using fitness values.
11: Generate new onlooker bees (new candidate solutions) using the probability of food source
12: New solution quality evaluation using fitness calculation
13: Adopt greedy selection process
14: Identify abandoned solutions and produce new solutions randomly using scout bee.
15: Identify and save the best solution
16: Cycle ← Cycle + 1
17: End While
18: Generate and return the best solution (wireless network) with minimum cost and maximum Throughput

Table 4
Simulation Parameters for scenario 2

Parameter	Range Lower	Upper
Max Iteration	1	100
Population Size	1	200
Bandwidth (Mbps)	14	10000
Latency (sec)	0.3	600
Cost (naira)	10	300

III. RESULT AND DISCUSSION

In this section, we report the results obtained from the simulations. The results for the first module are shown in Figures 3, 4, and 5. Figure 3 shows the decision made against the RSSI as the mobile signal deteriorates with increasing distance, while Figure 4 shows a graph of handoff decision against throughput. From the results shown in Figures 3, 4 and 5, the decision of when to handoff was made at -80 dBm for RSSI, the Throughput at 0.05Mbps and RSRQ at -25 dB. This occurred as the mobile moved farther away from the serving base station. Figure 6 shows the Fuzzy Logic Rule Viewer, which displays the output probability of handoff made at 0.875 (87.5%).

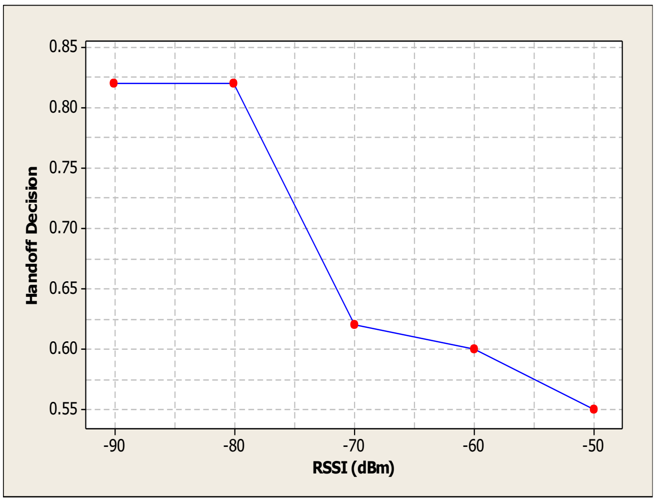

Figure 3: Graph of Handoff Decision against RSSI

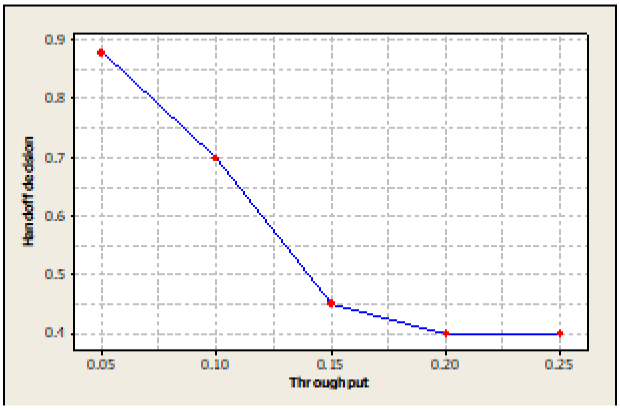

Figure 4: Graph of Handoff Decision against Throughput

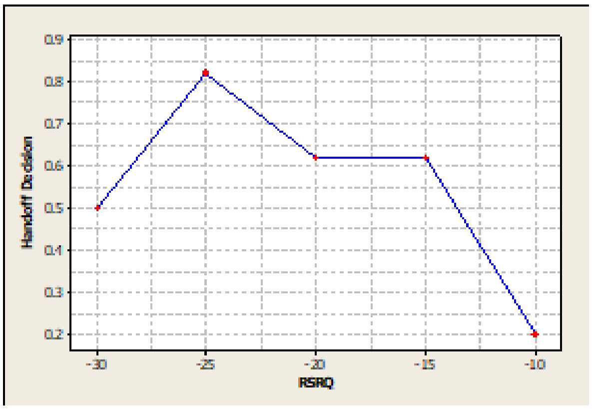

Figure 5: Graph of Handoff Decision against RSRQ

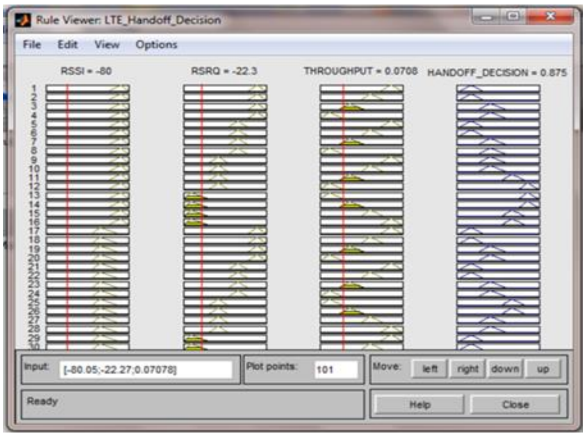

Figure 6: Rule viewer for Fuzzy Logic implementation

Figure 7 shows the result obtained from the selection process using the improved Artificial Bee Colony algorithm. The selected network of choice was chosen based on two attributes, network with the lowest cost and maximum throughput. The selected network was deemed beneficial in terms of providing the required QoS to users. From Figure 7, results were based on different QoS parameters, that the selected network is Het-Net 3 based on optimized parameters with Cost = 10 Naira/sec, SNR = 55.6 dB and Bandwidth 1132.24kbps.

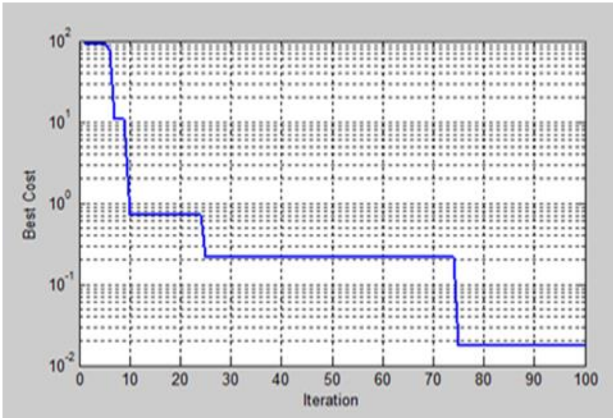

Figure 7: Simulation Result using Artificial Bee Colony

To compare the performance of the proposed algorithm and the existing GA algorithm, the execution time and the number of handoffs were measured against the existing Genetic Algorithm. Result from the comparison in Figure 8 shows the computational time for both algorithms in seconds. The proposed ABC algorithm has a faster execution time, thus performed better than the GA. This is an indication that the ABC converged faster in its search process.

For the number of handoffs, the proposed algorithm made an improvement during the selection process as shown in Figure 9. The number of handoffs was minimized when compared to that generated by the existing system. This is an indication that the proposed algorithm presented a better search accuracy to the existing GA algorithm. This will reduce the ping pong effect occurring in the environment.

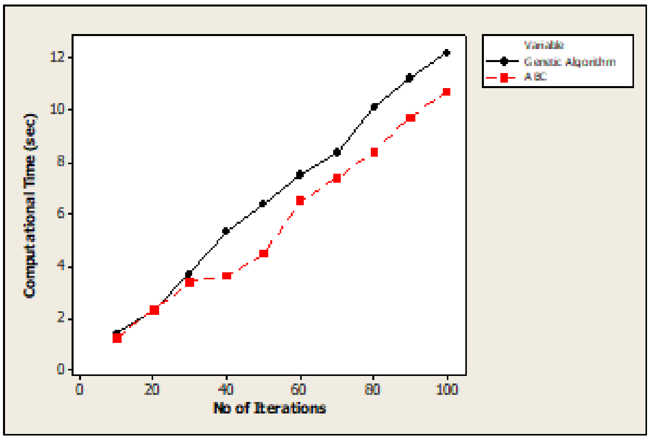

Figure 8: Computational time of ABC and GA

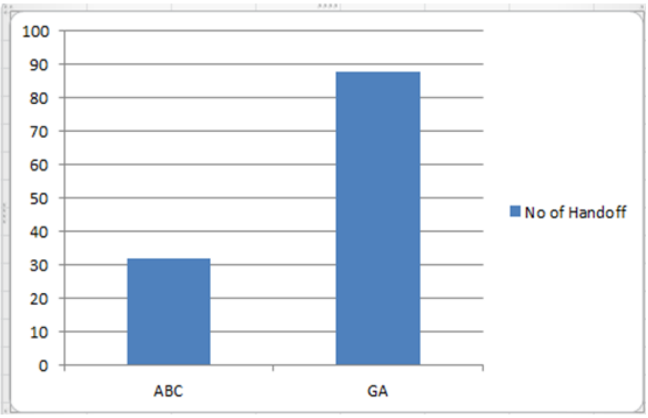

Figure 9: Comparison between ABC and Genetic Algorithm for Network Selection

IV. CONCLUSION

In this paper, a handoff approach for heterogeneous networks has been proposed. The main idea is leveraged on the application of artificial intelligence technique to predict handoff in a Heterogeneous environment. In our approach, we adopted a multi criteria fuzzy system to predict when and where to perform handoff and an improved ABC algorithm to select the best suited wireless network. The proposed handoff approach was able to solve the optimization problem associated with vertical handoff. With the ABC algorithm the selection of the best available network was achieved.

The results showed that the decision of when to handoff was made at -80 dBm RSSI with the Throughput at 0.05Mbps and RSRQ at -25 dB. This occurred as the mobile equipment moved farther away from the serving base station. Performance evaluation showed that the number of handoffs was minimized and computational time was also reduced.

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APPENDIX

Table 5
Computational Time Comparison for ABC and Genetic Algorithm

No of Iteration	ABC	Genetic Algorithm
10	1.24	1.43
20	2.32	2.34
30	3.38	3.70
40	3.63	5.32
50	4.47	6.38
60	6.50	7.50
70	7.40	8.39
80	8.39	10.09
90	9.72	11.23
100	10.71	12.21