Spectrum Allocation in Cognitive Radio - Simplified Swarm Optimization Based Method

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***Abstract:** Communication through wireless mode is accelerated its expansion in broad manner that make a way to communicate with different type of computing devices to interact each other. As the number of users continues to increase, there is a constant demand for the usability of radio spectrum, which is a limited resource.Therefore a maximum utilization of spectrum is necessary at any moment. Moreover it is desired to share the capacity of the bandwidth between the user's application on the basis of different channel utilization without compromising efficiency and fairness. Because cognitive system accommodate a dynamic spectrum allocation environment and it becomes an essential to compare performance in terms of Throughput, Latency, End-To-End Delay, Average Power Consumption, Average Adaptation Time and Average Total Utility were provided to illustrate the improved behaviour of the proposed system. A quality conscious spectrum assessment work is proposed, where spectrum bands are examined based on the requirements of application as well as the complex existence of the spectrum bands. The author used Simplified Swam Optimization (SSO) in this paper to communicate spectrum allocation and the performance of the proposed method is compared with the existing methods; Genetic Algorithm (GA) and Particle Swam Optimization (PSO) . It has been found that SSO gives an optimal solution than GA and PSO.*

***Key Words:** Cognitive Radio, Spectrum Sharing, Genetic Algorithm, Particle Swam Optimization and Simplified Swam Optimization.*

I. INTRODUCTION

Now-a-days communication network becomes the predominant due to multimedia applications where it requires a higher bandwidth and faster data rates [11]. The multimedia applications bring in different quality of services through third generation and fourth generation in order to achieve faster data rate in their allowed bandwidth requirements. The multimedia service and their information accessing convenience boost the development of the Wireless Multimedia. The patterns and efficiency of various devices have been heavily influenced by using higher bandwidth which is considered as a serious problem in the coming years. So, the next generation communication network has been designed to deal more efficiently with the explosive growth of data traffic and the emerging new technology scenarios in the future [5][10].

Thus, the expansion of communication network is required to accommodate the growth of the network communication which will be concentrated based on the capacity of the network.

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Next generation wireless networks have simple distributed controls and portable infrastructures which incorporate the technical issues related to the capability of the communication network where the feasibility and the cost of these techniques will be determined based on the growing demand [13]. While some society have suggested to maximize the bandwidth capacity in terms of Transmission Efficiency Per Megahertz (MHz) of spectrum and to improve the regional utilization of the spectrum which will be sufficient to meet the demand in the future. The basic techniques for expanding these wireless communication network capacity is necessary to include the expansion of the overall available radio spectrum [11]. The allocation of wireless frequency spectrum is considered to be the most challenging issue based on the demand and the limitations.

The Graphical User Interface (GUI) is the virtual progra m framework that allows the user to interact with other gadg ets based on different computational techniques. GUI has been used in different ways from standard computer to mobile devices including very small devices like watches[1] [7]. When different types of GUI arise, then its become an essential component to be checked to ensure the application achieves the user's desired performance. The cognitive system provides a dynamic spectrum allocation environment which brings necessary parameters such as Power Consumption, Throughput, Latency, End-to-End Delay, Average Power Consumption, Average Adaptation Timeand Average Total Utility. Unlike non-functional testing, GUI function testing ensures an appropriate interaction between the user and the interface of the application environment without dealing with the internal coding. Techniques for GUI functions are introduced using Genetic Algorithm (GA), Particle Swarm Optimization (PSO) and Simplified Swarm Optimization(SSO) are compared with each other.The effectiveness of the algorithm is demonstrated in the form of a graph by evaluating the parameters.

II. BACKGROUND WORK

Subhashree Mishra et al, proposed an algorithm for Cognitive Radio System where most of the communication taking place through a Multi-Carrier System. Here the cognitive system provides an environment of dynamic spectrum allocation [12]. Koroupi et al, suggested an innovative technique for utilizing Ant Colony System (ACS) and Fuzzy Logic (FL) which predominates communication networks suffering from lack of bandwidth and insufficiency of the spectrum [4].

Zhao et al suggested an interference synchronization mechanism to control spectrum sharing for Cognitive Radio (CR) networks, which is considered to be a powerful inference control strategy [8]. Yao Wang et al proposes a Cost and Connection Degree (CCB) algorithm that creates a new useful method to build a prototype to represent the overall utility of the process [14]. P.Vijayakumar and S.Malarvihi propose a Multiple-Input Multi-Output (MIMO) cognitive radio system with GA based power control, antenna selection and connection adoption are proposed to share the spectrum with minimal assurance [9]. FarokhKoroupi et al suggested a promising spectrum sharing clarification which avoids high spectrum costs and improving the utilization of spectrum resources, particularly Wider-Coverage, Massive-Capacity, Massive-Connectivity and Low-Latency [3]. The need for spectrum capacity is constantly increasing with the advancement of wireless communication technologies and the lack of wireless spectrum resources where Cognitive Radio has described as a potential spectrum sharing system. It is fundamentally essential component which formulates an alternate way to avail the entire spectrum resources need on demand efficiently. Cognitive Radio networks consist of highly spaced base stations, numerous clients and sensor nodes. Spectrum allocation of secondary nodes is influenced by a variety of factors, which includes bit error rate, availability of free carriers, transmitting capacity and consumer need, etc., The flexibility exposure to the spectrum is its essential concept and it can use the unused spectrum efficiently without compromising user rights as many clients will share a part of the spectrum.

III. SIMPLIFIED SWARM OPTIMIZATION (SSO)

An integrated spectrum distribution system for Cognitive Radio Networks (CRN) is formed in which spectrum bands are defined with the existences of spectrum band by considering the application requirements [6]. Moreover, subcarrier allocation has been designed to meet the different performance based on Simplified Swarm Optimization Algorithm for Cognitive Radio users in CRNs. Selection of channels is essential which enables the CR to select the best channel among the sensed channels collected where the CR must able to adjust dynamically with the physical parameters such as bandwidth, strength and activity. Initially, the proposed scheme detects the reliability of the primary users which operates with multiple Primary Users (PU) networks. In the typical PSO, each particle has its own fitness value, which is determined by a fitness function at its current position in order to be optimize. PSO starts with the initial population of random particles with random positions and velocities which are updated from iteration-to-iteration within problem space. The particles travel the iteration in a multidimensional search space with their velocities constantly being updated by the perception of the particle itself. In Simplified Swarm Optimization (SSO) exchanges the local search where by initializing the amount of swarm population size, the cumulative generation number and three preset parameters are initially been calculated. The position value of the particle in each dimension will be maintained or updated by its pbest value or the gbest value in each generation or replaced by a new random value in accordance with this procedure[2]. The following equation is used to calculate the best fitness value.

$$x_{id}^{t} = \begin{cases} x_{id}^{t-1}, & \text{if } rand() \in [0, c_w], \\ p_{id}^{t-1}, & \text{if } rand() \in [c_w, c_p), \\ g_{id}^{t-1}, & \text{if } rand() \in [c_p, c_g), \\ x, & \text{if } rand() \in [c_g, 1). \end{cases} \qquad \text{Equ (1)}$$

In this equation, i = 1, 2, . . . , M, where M is the swarm population. $X_i = (x_{i1}, x_{i2}, \ldots, x_{id})$, where x_{id} is the position value of the i-th particle with respect to the D-th dimension of the feature space. Cw, Cp and Cg are three predetermined positive constants with Cw<Cp< Cg. $P_i = (p_{i1}, p_{i2}, \ldots, p_{id})$ denotes the best solution achieved so far by itself (pbest), and the best solution achieved so far by the whole swarm (gbest) is represented by $G_i = (g_{i1}, g_{i2}, \ldots, g_{id})$. The x represents the particle location value in each dimention which will be retained or updated by its pbest value or the best value in each generation from random function and(), where the random number lies in between 0 and 1.

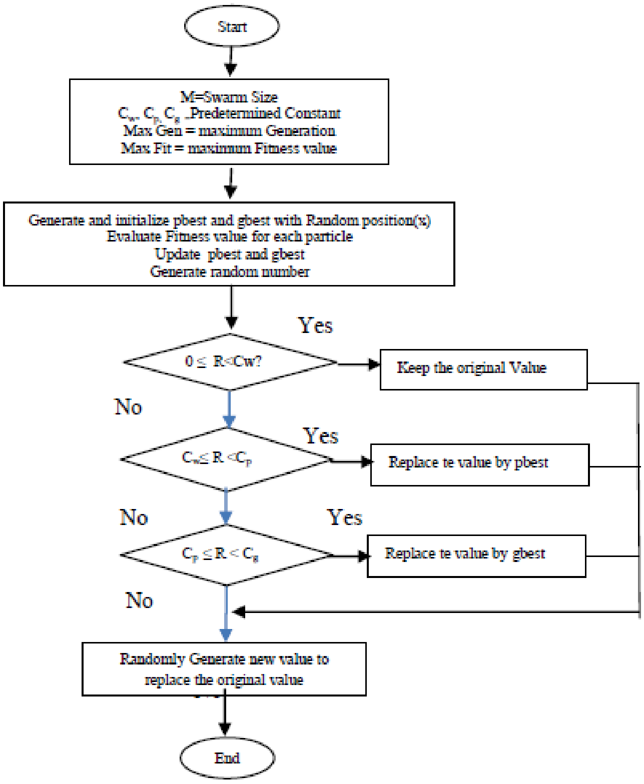

Figure-1 Flow Chart for SSO Algorithm

The proposed algorithm aims at maximizing the number of satisfied users under bandwidth constrains and ensures the quality of service. Since cognitive system contributes a dynamic spectrum allocation environment, it's essential to conduct dynamic spectrum allocation. Nevertheless, PSO suffers from premature convergence which results in the particle having difficulty in achieving the best fitness value.

In genetic algorithm, the population converged too early for an optimisation problem. In order to improve the performance and overcome the drawback of GA and PSO this paper proposes a new Simplified Swarm Optimization (SSO) algorithm whereby incorporating it with the new local search strategy which finds a better solution.

IV. IMPLEMENTATION

Network Simulator OPNET is used to simulate 1000 nu mber of nodes in an area of 5000 square meters which is randomly placed. Network node are categories to configure and to characterize different types of nodes similar to Servers, Gateway, Routers, Laptops, Mobile devices and IoT based Wireless Sensors. Depending on node configuration, all common protocol types such as IEEE 802.11b/g/n are used in mixed mode in order to reflect a standard real world interaction, flexibility and network traffic are randomized. Simulation is performed with the simulation tool OPNET for 1-hour real world time and the parameters Throughput, Latency, End-To-End Delay, Average Power Consumption, Average Adaptation Time and Average Total Utility were logged in every 6 minutes for 60 minutes duration. Visual Studio IDE is used to create the user interface and compare the performance of GA, PSO and SSO. A computer with Intel ® Core ™ i5 processor, 4GB RAM is used to run the experiment. Simulation is performed for one hour simulation time with 10 minutes time stamps. OPNET simulation setup is given in Figure-2.

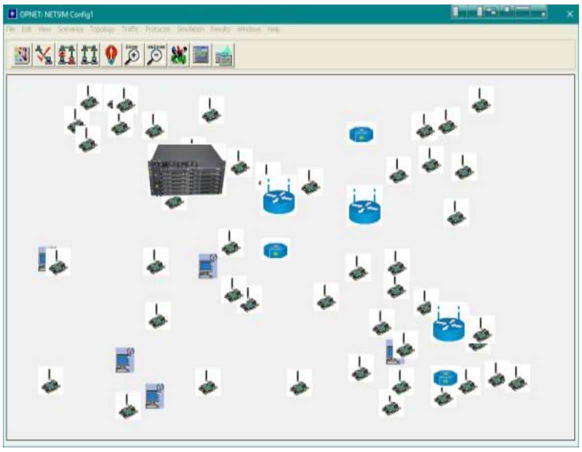

Figure-2 OPNET Simulation Setup

V. RESULTS AND DISCUSSION

Network metrics such as Throughput, Latency, End-To-End Delay, Average Power Consumption, Average Adaptation Time and Average Total Utility are measured 10 times in a simulation hour with 10 minutes timestamps. Results of existing methods GA, PSO and proposed SSO are logged in a report files and graphs are plotted based on the results for the above network metrics which is already defined. Throughput refers how much data can be transferred from sender to receiver in a given amount of time.

Throughput = Number of Packets sent / Time Taken. It is the actual amount of data that is successfully sent/receive in a acommunication link. It is one of the important metrics of network that dissembles the quality of the network. Measured throughput for GA, PSO and SSO are given in Table 1.

Table 1. Throughput (bps)

Time Stamp	Throughput		
	GA	PSO	SSO
1	2432964	2567453	2723976 (bps)
2	2403172	2544284	2704200 (bps)
3	2373415	2521174	2684539 (bps)
4	2343530	2497877	2664740 (bps)
5	2313857	2474739	2645007 (bps)
6	2284000	2451635	2625395 (bps)
7	2254328	2428708	2605601 (bps)
8	2224380	2405396	2586034 (bps)
9	2194544	2382467	2566082 (bps)
10	2165184	2358778	2546276 (bps)

The parameter Throughput is higher for SSO when compared with GA and PSO as per the observation of the graph in Figure-2 as well as in Table 1 observations. SSO takes an average time (or) Throughput of 2723976 (bps) which is higher than other Throughput 2567453 (bps) for PSO and Throughput 2432964 (bps) and 80 of GA during first Time Stamp. This higher value reflects the higher efficiency of the proposed method SSO.

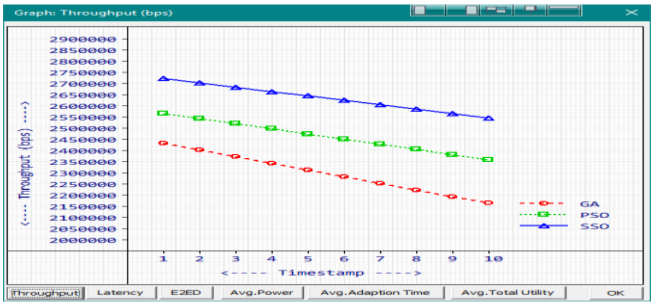

Figure-2. Throughput (bps)

Latency:

Latency = Propagation Delay + Serialization Delay Propagation Delay = Distance / Speed Serialization Delay = Packet size (bits) / Transmission rate(bps)

Latency is the time it takens for a packet to get across the communication link form sender to receiver. It is measured in units of time-ms (Milli Seconds)

Measured latency for GA, PSO and SSO are given in table 2.

Table. 2. Latency (mS)

Time Stamp	Latency		
	GA	PSO	SSO
1	60	50	31 (mS)
2	55	51	40 (mS)
3	58	51	32 (mS)
4	62	51	32 (mS)
5	61	43	32 (mS)
6	54	42	39 (mS)
7	63	49	36 (mS)
8	62	44	32 (mS)
9	59	50	40 (mS)
10	62	49	32 (mS)

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The latency value is lesser for SSO when compared with the GA and PSO according to the observation of the table 2. In the first time stamp, SSO takes an average period of 31(mS) which is less than other timings 50 (mS) for PSO and 60 (mS) for GA. The lower value indicates the proposed SSO is higher in efficiency.

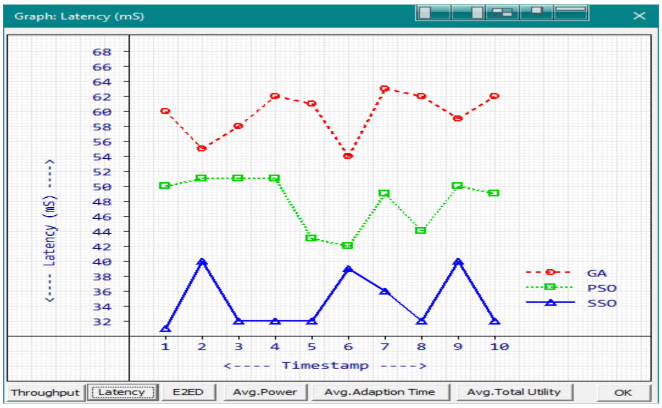

Figure-3. Latency (mS)

End-to-End Delay:

The formula for end-to-end Delay I=(P + (N-1))*L / R where, P = Packets, N = Number of links, L = Packet Length, R= Transmission Rate.

End-to-End delay is the time needed for the destination application to get the packet generated by the source application. End-to-end delay consists of two parts: end-point application delay and network delay. End-point delay is the delay introduced by the end-point applications. Network delay is defined as the time the first bit of the packet is put on the wire at the source reference point to the time the last bit of the packet is received at the receiver reference point.

Table-3. End-to-End Delay (mS)

Time Stamp	End-to-End Delay		
	GA	PSO	SSO
1	305	277	260 (mS)
2	333	303	284 (mS)
3	350	324	314 (mS)
4	378	348	335 (mS)
5	398	376	361 (mS)
6	429	387	378 (mS)
7	453	416	410 (mS)
8	482	445	441 (mS)
9	512	476	467 (mS)
10	527	491	482 (mS)

In contrast with the GA and PSO, the End – to – End Delay parameter I s lower for SSO as per the observation from the Table-3 and the graph in Figure-4. During the period of first time stamp, SSO takes an average time of 260 (mS) which is lower than other timings PSO 277 (mS) and 3059mS) for GA. This lower value reflects the proposed SSO has higher efficiency.

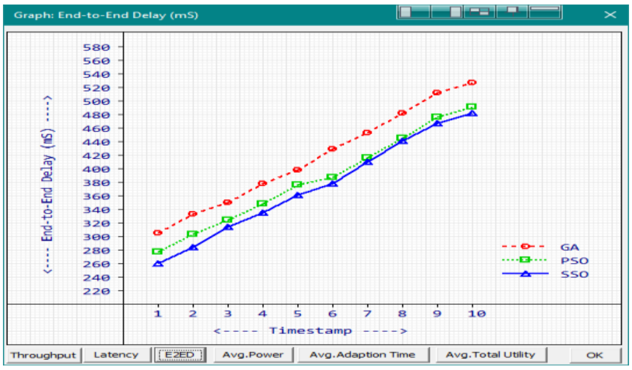

Figure-4. End-to-End Delay (mS)

Average Power Consumption:

Power consumption is measured in mWh. The power $P = V \times I$, where V refers the Voltage and I refers the current. OPNET is capable of measuring the average power utilized in a node by tracking the power consumption of all nodes. OPNET provides the initial power randomly to replicate the real-world environment. OPNET handles the voltage and current information of all nodes as a set $P = \{(V_1, I_1), (V_2, I_2) \ldots (V_n, I_n)\}$. This set is maintained throughout the simulation process. OPNET supports heterogeneous network environments, thus each node can have different V,I parameters. Initially the simulator allots V and I parameters randomly for every node. The average power consumption for a network transaction is calculated using the following formula.

$$P_a = \frac{1}{n} \sum_{i=1}^{n} (V_i \times I_i)$$

where n is the number of nodes in the simulation. Measured Average Power Consumption for GA, PSO and SSO are given in Table-4.

Table-4. Average Power Consumption (mW)

Time Stamp	Average Power Consumption		
	GA	PSO	SSO
1	80	69	54 (mW)
2	91	77	61 (mW)
3	104	88	71 (mW)
4	115	96	79 (mW)
5	129	105	90 (mW)
6	136	110	91 (mW)
7	156	127	97 (mW)
8	166	129	109 (mW)
9	176	138	118 (mW)
10	192	141	131 (mW)

The main difference with the GA and PSO, the parameter Average Power Consumption (mW) is lower for SSO as per the observation from Table-4 and Ffigure-5. The duration taken for Average Power Consumption the first time stamp in Table-4 reflects that SSO takes an average time of 54 (mW) which is lesser than other timings such as 69 (mW) for PSO and 80 (mW) for GA. This lesser value shows the higher efficiency of the proposed method SSO.

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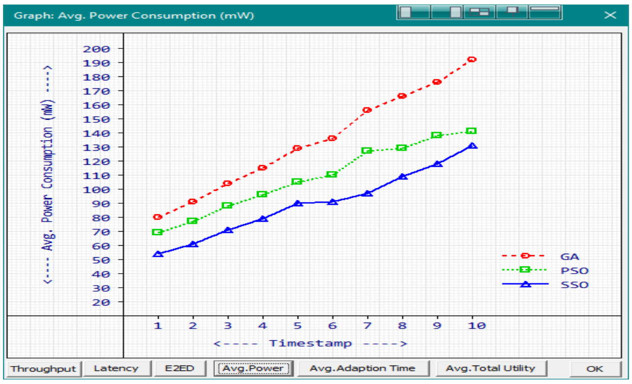

Figure-5. Average Power Consumption (mW)

Average Adaptation Time:

Adaptation time refers the time duration taken for a network cluster with a base frequency to append a new node. Let α be a set of adaptation times of new nodes $\{\alpha_{N_1}, \alpha_{N_2}, \_ \alpha_{N_n}\}$, the average adaptation time is calculated as $T_\alpha = \frac{\sum_{i=1}^{n} \alpha_{N_i}}{n}$ where n is the number of new nodes added the network band. Measured Average Adaptation Time for GA, PSO and SSO are given in Table-5.

Table-5. Average Adaptation Time (mS)

Time Stamp	Average Adaptation Time		
	GA	PSO	SSO
50	120	107	98 (mS)
100	601	553	535 (mS)
150	1098	1002	958 (mS)
200	1584	1448	1393 (mS)
250	2069	1867	1825 (mS)
300	2551	2307	2265 (mS)
350	3022	2784	2708 (mS)
400	3534	3218	3122 (mS)
450	3988	3656	3562 (mS)
500	4538	4092	3974 (mS)

Unlike the GA and PSO, the Average Adaptation Time (mS) parameter is lesser for SSO as per the observation from the Figure-6 and the Table-5. SSO takes an Average Adaptation Time of 98 (mS) which during the first time stamp is lesser than other timings107 (mS) for PSO and 120 (mS) for GA. This lesser value reflects the higher efficiency of the proposed SSOmethed.

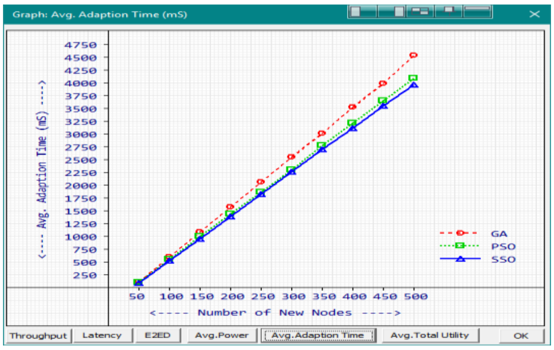

Figure-6. Average Adaptation Time (mS)

Average Total Utility:

Average Total Utility is calculated by averaging the total utility of the network resource (spectrum) throughout the simulation. Total utility is calculated for every time slices between two timestamps and the average of these values is represented as average total utility. Measured Average Adaptation Time for GA, PSO and SSO are given in Table-6.

Table-6. Average Total Utility (%)

Time Stamp	Average Total Utility		
	GA	PSO	SSO
50	82.01	85.04	87.70 (%)
100	81.23	84.25	86.86 (%)
150	80.32	83.19	85.74 (%)
200	79.23	82.40	85.11 (%)
250	79.01	81.26	84.07 (%)
300	77.25	80.13	83.03 (%)
350	76.27	79.68	82.56 (%)
400	76.36	78.83	81.55 (%)
450	74.07	77.36	79.91 (%)
500	73.77	76.51	79.09 (%)

The observation from the Figure-7 and Table-6 the Average Total Utility percentage is higher for SSO when compared with the GA and PSO. SSO takes an Average Total Utilityof 87.70 (%) which is higher than other timings 85.04 (%) for PSO and 82.01(%) for GA during first time stamp. This higher value reflects the higher efficiency of the proposed method SSO.

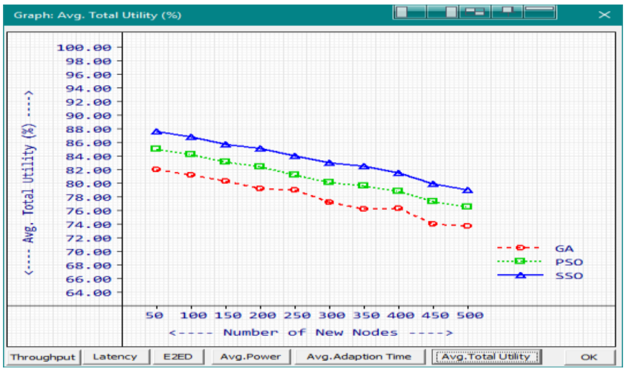

Fig. 7. Average Total Utility (%)

VI. CONCLUSION

As the Particle Swarm Optimization algorithm suffers from premature convergence which makes it difficult for the particle to obtain the best fitness value. In Genetic Algorithm the population convergence is too early for an optimisation issue. The theoretical and simulation results expose that the proposed Simplified Swarm Optimization Algorithm, where the new local search techniques is merged to provide a better optimization and justifies that SSO is better than GA and PSO. This model is appropriate for numerous measurements of parameters such as Throughput, Latency, End-To-End Delay, Average Power Consumption, Average Adaptation Time and Average Total Utility. For specific given period of time and optimal channel conditions, our model assumes a finite number of nodes. A new method based on Simplified Swarm Optimization technique is implemented and its performance enhancement is tested on the basis of the simulation results to enable better resource utilization.

For heterogeneous environments, SSO is suggested by providing a lucide bridge for optimality between two different types of algorithms.

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