

## Energy Consumed Optimization Using Agent-Based GAPSO Scheme in Mobile Networks

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# Energy Consumed Optimization Using Agent-Based GAPSO Scheme in Mobile Networks

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**Abstract**— As a significant constraint on mobile devices, battery power is often consumed very quickly during use. In this paper, a hybrid GAPSO system based on a combination of genetic algorithms (GA) and particle swarm optimization (PSO) is utilized as a solution for energy management in mobile networks. The proposed energy management solution uses mobile agent technology to allocate power efficiently in mobile networks. An extensive simulation study, to evaluate performance, shows the feasibility of the proposed approach, where energy consumption is significantly reduced.

**Keywords**— *genetic algorithms; particle swarm optimization; mobile agent; channel allocation; energy-constrained mobile devices.*

## INTRODUCTION

A cellular communication system is made up of mobile units connected by a radio network to a switching equipment infrastructure that connects the various components of the system and provides access to the regular (fixed) PSTN. To cover a specific area or cell, a number of transceivers known as base stations (BS) are positioned in key locations. In a typical mobile computing application, a large number of mobile nodes, also known as mobile hosts (MHs), dispersed throughout a geographic neighborhood, communicate with centrally located and controlled base stations as shown in figure 1 [1-3].

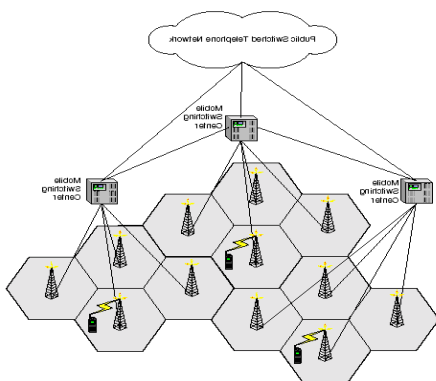


Figure 1: Mobile cellular Network.

Concerns regarding the optimal use of this non-renewable resource have been raised by wireless communications' energy-intensive nature. For designers of wireless communication systems, energy consumption has become a major concern as mobile users have increased. By carefully considering the use of available resources, mobile systems, communications equipment, and wireless protocols can save energy through their carefully designed architecture [4]. A

mobile agent technology is employed in a mobile network channel allocation system that uses less energy, which is presented in this paper.

This work is structured as follows. The energy-saving problem, along with the role of mobile agents in mobile computing, is discussed in section 2. In section 3, the literature review is displayed. A brief overview of the GAPSO model is presented in section 4. The proposed scheme for energy-efficient power management, with subsections to elaborate on the mobile agent technique and the scheme modules, is shown in section 5. Experimental results to evaluate the performance study of the proposed approach with the obtained observations are given in Section 6. The proposed work has been compared with an agent-based GA model in Section 7, followed by the concluding remarks in Section 8.

## 1. ENERGY IN MOBILE NETWORKS

One of the main problems with mobile computing systems has been energy consumption. Many researchers have addressed issues with power consumption in mobile environments [4–9]. Every layer of the protocol stack and the entire mobile system should take energy conservation into account [4]. Understanding various operational costs in relation to energy consumption is necessary for solving power management issues.

Energy is wasted when a channel performs poorly for an extended length of time and data packets are repeatedly transmitted in the hope of success. Generally, retransmission of packets due to channel errors results in a decrease in the system's throughput. Additionally, there is a delay in the packets that are queued at the base station, which causes both the sender and the receiver to use a lot of energy during transmission. This is true as long as the packets are retransmitted and the acknowledgements are done. Much energy can be saved by lowering these retransmissions [4, 9-11].

Only devices that try to reduce the duration of the radio's operation can save power. By selecting a transmission time that minimizes the chance of failure and subsequent retransmission, one such mechanism lowers the volume of radio traffic flow. Periodically turning off the radio's transmitter and receiver is part of power management. An upper limit on how long the source node will listen before timing out is crucial.

## 3. RELATED WORKS

A channel allocation model to minimize the consumed power in a cellular network is proposed in [4], using GA agent-based, where a power management solution is offered to determine the most energy-efficient channel allocation in that network.

A partial computation offloading method is suggested in [10] to lower the total energy usage of edge servers and SMDs. A hybrid metaheuristic algorithm called genetic simulated annealing-based particle swarm optimization (GSP) formulates and resolves a nonlinear constrained optimization problem to produce a near-optimal solution.

The research paper in [11] aims to maximize the secrecy capacity in mobile communications. In particular, it optimizes the sum proportional fairness function for both vehicular user equipment and cellular user equipment after optimizing the secrecy capacity of vehicular user equipment. The genetic algorithm (GA) is utilized for solving this problem.

In order to minimize call blocking and handoff errors in mobile network systems, a PSO-based technique is presented to maximize channel utilization in a mobile computer network. Without becoming stuck in a local maximum, the PSO algorithm finds a better solution with a quick rate of convergence [12].

The suggested work that applied the hybrid GAPSO scheme to the design of recurrent neural/fuzzy networks in [13] produced a better solution without local maximum trapping and a faster convergence rate.

In [14], hybrid techniques mixing genetic algorithms (GAs) and particle swarm optimization (PSO) are presented to allocate tasks to resources efficiently. The proposed strategy optimizes the channel allocation in the network system.

#### 4. THE GAPSO MODEL

The number of iterations is specified as an algorithmic parameter by the GAPSO algorithm, which begins by generating a random population [13 and 14]. The initialized population is applied to the first half of the GA algorithm's defined iterations; if the number of iterations is ( $n_i$ ), the GA algorithm is repeated ( $n_i / 2$ ) times. The fitness function's measurements, the population size, and the method used to encode solutions into chromosomes and particles all have a major impact on the GA algorithm's performance. The suggested algorithm's complexity is decreased by using ( $n_i / 2$ ) number of iterations [15].

At each iteration, the GA algorithm employs GA operators to gradually improve the solutions (chromosomes) (i.e., selection, crossover, and mutation). The resulting chromosomes are sent to the PSO algorithm in the second half of the designated iterations. In the PSO algorithm, the chromosomes are referred to as particles, these particles improve with each iteration of the algorithm. The particle with the lowest fitness value is the one selected as the symbol to solve the problem.

The hybrid GAPSO algorithm is initialized using a predefined number of iterations. In the initial iteration, a solution is introduced at random. Following the initial iteration, a set of new populations is created, and a set of suggested solutions is produced by recursively improving them using the earlier solutions. The GA algorithm represents the first part of the suggested algorithm. The solutions returned by the GA algorithm are fed into the PSO algorithm along with the remaining computed iterations in order to determine the optimal solution among the solutions generated by the GA algorithm. As seen in figure 2, the PSO algorithm refers to the solutions as particles.

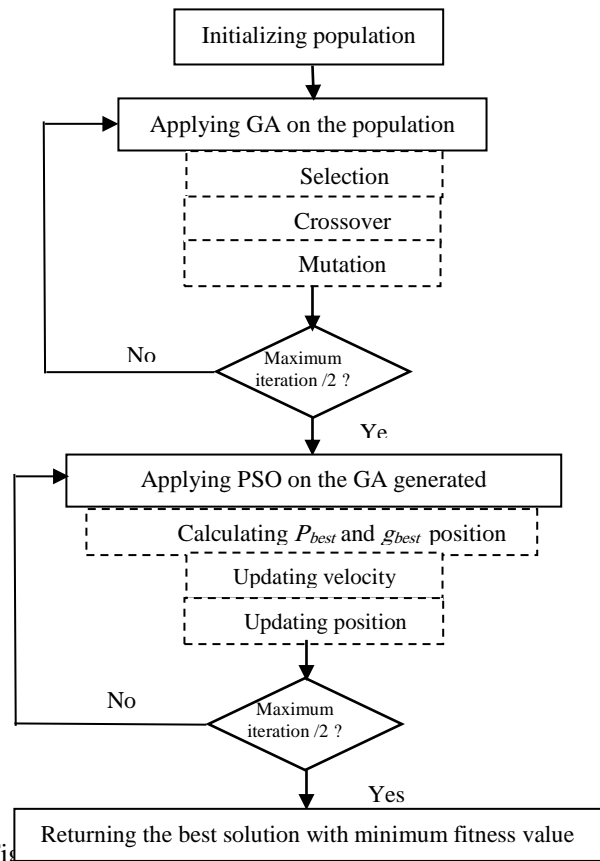


Fig. 2

#### 5. THE AGENT-BASED GAPSO SCHEME

The base station uses a lot of energy in its constant search for free channels for the mobile hosts. One important factor in BS power consumption is searching time. Reducing the amount of time spent communicating with the base station while choosing a channel can help conserve energy. Channels may have a high likelihood of colliding, so there might be congestion in the channel. For some channels, this results in a longer search process than for others. The cell or channel is disregarded for the response if the searching time surpasses a predetermined threshold. Additionally, it is anticipated that the devices may alternate between sleep and wakeup modes while conducting the search [4-11].

In order to lower the likelihood of interference between transmissions taking place on the same channel, thus lowering the chance of wasting bandwidth and impacting an already existing transmission, where this channel interference leads to increased power transmitter consumption, this may be accomplished by using an effective co-channel strategy, which will lessen the energy usage. We have previously suggested the channel assignment approach in the FTCA model that employs an effective co-channel approach [3]. It also utilizes a restricted channel pool for the crossing hosts [3, 16, 17]. The same approach has been followed in this study.

Dynamic adaptation is one of the characteristics of mobile agents (MAs). It eliminates network latency, dependability, and fault-tolerance, and increases network traffic. Mobile agents are used in this work to minimize computation time and make dynamic decisions. Information about the state of

the free channels and the search time to nearby cells has been gathered by the cells using mobile agent technology. The MA will fetch the information, such as which neighboring cells offer the minimum-power-cost service, so that the borrower cell can make the borrowing decision accordingly. In the network, each agent operates independently of the others and maintains its entire state. [4, 18-21].

### 5.1 Mobile agents

The MA is a particular kind of application that spreads across the network either on a regular basis or at specific times (as needed by the applications). As it moves from node to node, it handles data processing independently. The agent has the special capacity to move itself between systems inside a network. By making use of the network infrastructure, MA can operate in a separate remote location, retrieve and analyze the findings, collaborate with other sites, and when it has finished the assigned tasks, MA returns to his site. An agent can function in the networking area even if the user logs out of the network. At a later moment, the mobile device may reconnect to retrieve the agent [18 and 22]. Unconnected computing, also known as wireless computing or, network management, mobile computing, personal assistants, and parallel processing using mobile agents are areas where mobile agents make a significant contribution. [19–24]. Mobile agents are especially interesting in mobile-computing environments because they allow an agent to continue operating even in case of a network link failure by migrating to the other network side. Most significantly, as illustrated in figures 3 and 4, an agent can select various migration strategies based on its task and the available network conditions [4 and 25].

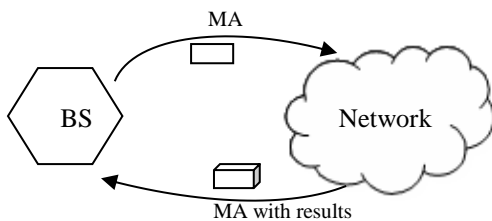


Figure 3. Mobile agent process.

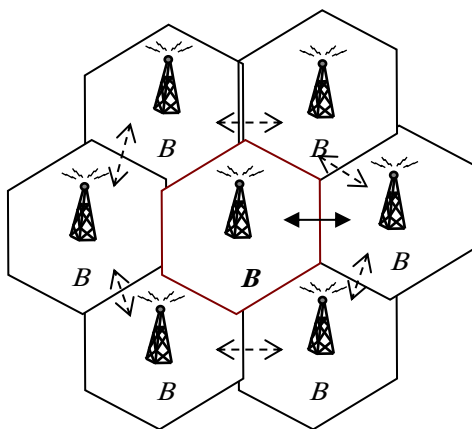


Figure 4. Migration of MA between cells.

### 5.2 Explanation of the model

Sending an acknowledgement (ACK) for each individual packet or retransmitting a lot of unnecessary signals is a very inefficient use of energy. According to the plan, a transmitter with a pending data transaction only has one timer linked to it. The timer is set to the anticipated response time of the intended recipient if the transmitter has just started a transmission and a request has been sent to the intended recipient. If there is a timeout, the request is sent again and a new timer is started. The connection request will be terminated after a predetermined number of retries. The timer's expiration indicates that the recipient did not send back an acknowledgment. The connection is terminated if the transmitter does not receive an acknowledgment even after making several ACK requests. Before the connection is dropped, there is a maximum number of attempts to retransmit in this manner. Data packets will continue to be retransmitted until they are received correctly or a timeout occurs. Whenever necessary, the MA is moved between nodes. The agent presents the findings to the borrower BS [4] upon completion of execution.

A threshold selection operator was added to the simple GA in one of our previous works [26]. In order to enhance network system performance, the threshold selection operator has also been applied to a channel allocation problem [17]. For instance, during the threshold time in a communication session, a cell  $C_i$  can borrow at least 80% of the necessary channels from its neighbors if it needs them for its mobile hosts. As a result, power is conserved with a suitable blocking rate. The minimum power cost among the nearby cells is used to determine the computation time. The channels are arranged in a unique order, with the highest frequency channel having the highest order and the lowest frequency channel having the lowest order. A timer is set to determine the maximum delay in making a channel allocation decision in order to minimize power consumption and maintain an appropriate timer value at the node while anticipating acknowledgements. It is assumed that packet sizes and transmission times through the cells are distributed randomly.

The energy ( $EC_i$ ) consumed by  $C_i$  during a session is calculated as follows:

$$EC_i = N \times P \times T \quad \dots\dots\dots (1)$$

Where:

The base station in cell  $C_i$ . sends  $N$  packets.

A package's size is  $P$ .

The average amount of time it takes to transmit one byte of data when looking for free channels from neighbors of  $C_i$  during a session is  $T$ .

A list of base stations to visit is carried by the mobile agent. It can also search for new, intriguing locations to visit. An agent needs to be able to communicate with other agents in order to complete its task. The base station should be able to grant access permissions and verify who owns the agent. Before sending the collected data over the network to the owner node, agents are sent to nearby base stations to pre-analyze and assess it based on the authentication. The quantity of signaling messages brought on by location updates may be decreased with the use of these data. A mobile agent will be prepared to reconnect to its host or move to another node to carry out additional tasks within the

network once it has completed its work at the base station. The ability to create an agent request, launch the agent during a brief connection session, and then quickly disconnect is the benefit of using agents. Only the pertinent data is returned after the mobile agent completes its task on the network. By reducing the signaling messages with neighbors brought on by the free channel searching process, MA lowers the system's energy consumption. For a predetermined amount of time, MA will move and gather data. In order to minimize the overhead retransmission of the borrower cell, it can jump to or from one node to another while ignoring a disconnected or failed node. The MA can monitor when a channel is available for a waiting call or choose the appropriate channel for a call. When compared to conventional techniques that do not employ the mobile agent, it increases the algorithm's competitiveness and efficiency [4].

BS analyzes MA's data and selects the best channel to send it to MH. More reliable channels to reduce transmission and retransmission failures that consume transceiver power can be selected and allocated. In this energy model, we incorporate the effect of the channel condition into the energy model by redistributing the channel allocation, in each cell whenever possible in terms of the channel quality [4, 16] Each cell has a number of reserved channels that are immediately transferred to the mobile host. At the same time, however, the cell will look for a new channel. When a new channel is received, it is assigned to a mobile host, so the reserved channel pool remains unchanged.

The following are a few of the modules used in GA.

**5.2.1 Initial population**

The channels are allocated to each cell according to the initial demand, and the hosts are first distributed among the cells in proportion to each cell's capacity. As a result, the values for every chromosome array are acquired.

**5.2.2 Chromosome structure used**

In this agent-based GAPSO scheme, each cell in the simulated mobile network is represented by a chromosome, and each chromosome structure is represented by an array of length 5. The five positions of the chromosome array are allocated to the number of channels, hosts, packets, average searching time, and energy consumed.

The chromosomes are integrated to provide data about the entire network region.

**5.2.3 Selection**

The experience of determining the population goodness of the channel allocation problem is used to determine the threshold values. The number of open channels and blocked hosts in each generation determines the issue at hand. The network system's performance has been enhanced by using the threshold selection operator [17, 26].

**5.2.4 Fitness function used**

The total energy consumed ( $E_t$ ) in the network during a session is derived from equation (1) as follows.

$$E_t = \sum_{i=1}^n E_i \dots\dots\dots (2)$$

where n is the entire number of base stations that participated in the session.

The total energy  $E_t$  in (2) must be minimized in order to optimize the energy used by the designed network system. This function provides the total amount of energy used during a communication session at any given time T.

**6. SIMULATION EXPERIMENTS**

The performance of the GAPSO agent scheme is evaluated in this section. Since it is found that the solution converges by 500 generations, the experiment is carried out up to 500 generations. The experiment is run over a range of time periods and sessions. Each graph includes the relevant inputs.

**6.1 Sessions experiments**

The x-axis represents the number of channels applied and the y-axis denotes energy consumed in MW. Results obtained for session 1 are summarized in figure 5.

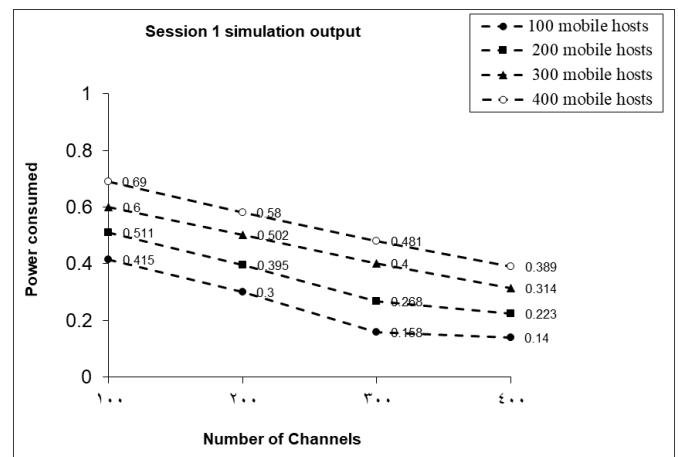


Figure 5. Results of session 1.

Similar simulation parameters for different sessions (time instances) are utilized. The end results are summarized in the graphs as shown in figures 6–8.

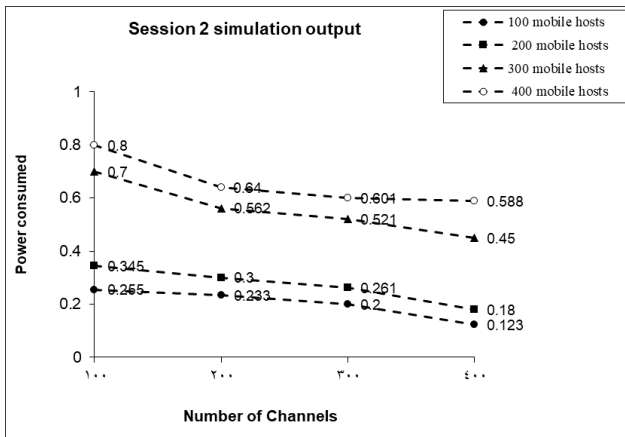


Figure 6. Results of session 2

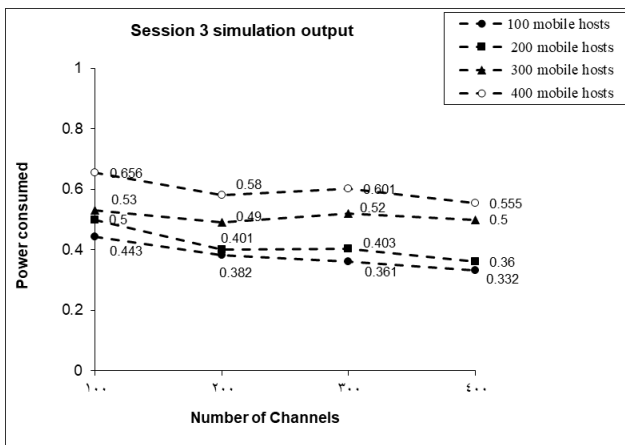


Figure 7. Results of session 3

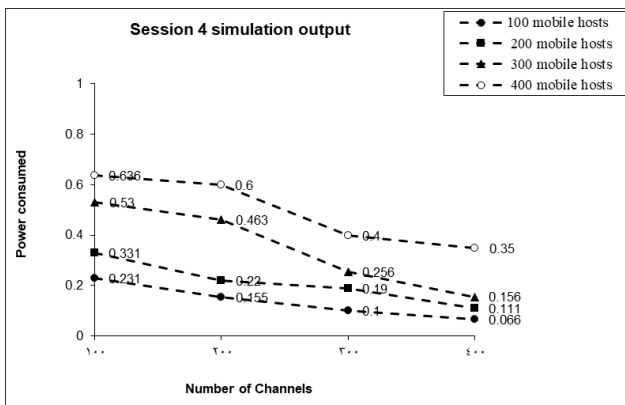


Figure 8. Results of session 4

## 6.2 Average results of all sessions experiments

The average result of the four sessions is shown in figure 9.

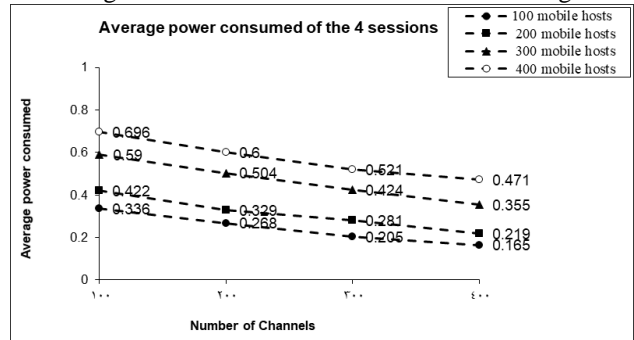


Figure 9. Average results of the four sessions

## 6.3 Impact of adding mobile agent in GAPSO scheme

The experiment is conducted with two scenarios, in order to examine the impact of adding mobile agent technology to the GAPSO model. The results are compared both when adding mobile agent and without mobile agent. Figure 10 displays the results that were obtained.

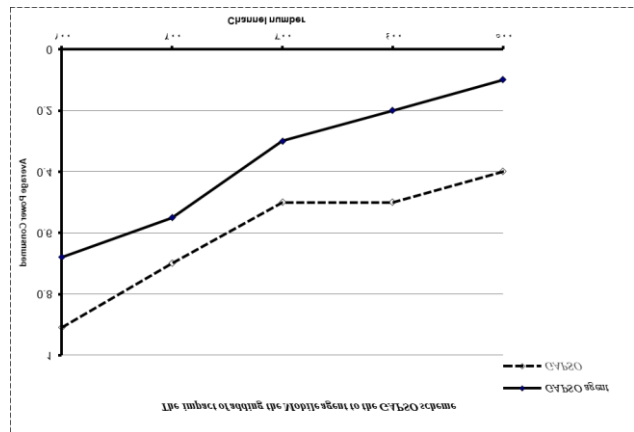


Figure 10 Impact of adding MA to the GAPSO model

## 6.4 Observations

The graphs in figures 5–9 make it evident that a significant reduction in power consumption has occurred. The GAPSO scheme's use of mobile agents significantly enhances network system performance.

Power consumption rises as the number of mobile hosts and channels both increases. This is because base stations are searching for more free channels for longer periods of time. Nevertheless, the produced results remain acceptable in terms of power usage being optimized.

Figure 10 compares the performance output with and without adding the mobile agent. It shows that power consumption is decreased when the mobile agent technology is introduced, so the network system performance is enhanced.

## 7. Comparative study

The proposed agent-based GAPSO scheme is also evaluated by comparing its performance with the agent-based GA model proposed earlier in [4]. For fair comparison, the same simulation environment is applied

for both schemes in terms of number of channels and mobile hosts, etc., the result is presented in figure 11.

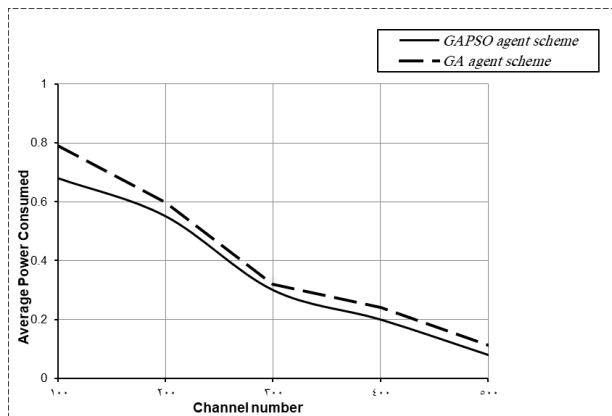


Figure 11. Average power consumed with different number of channels

It is obvious from the performance graph, in figure 11, that the proposed agent-based GAPSO scheme outperforms the agent-based GA model in consuming less power.

## 8. CONCLUSION

In this paper, a mobile agent technique is utilized in the GAPSO scheme with the purpose of optimizing the consumed power in the wireless mobile network. A power management solution is presented to find the energy-efficient channel allocation in a mobile cellular network.

The suggested model is a useful strategy for reducing the network's power consumption while searching for free channels. The most effective way to reduce the signaling load in cellular networks is to utilize mobile agent technology. The simulation experiment shows that the systems' performance is enhanced by the mobile agent's effective and well-managed across the mobile network.

The efficiency of the suggested work in terms of power consumption is demonstrated by an experimental comparison study with another earlier agent-based GA work, where the performance graph illustrates the robustness of the proposed scheme. We plan to monitor the impact of power reduction in the wireless network system for other parameters.

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