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# User Centric Optimization in MANETS using Firefly Algorithm

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**ABSTRACT**

The world is moving into a direction where the humans are assisted by controlling systems to give outmost comfort to the user. Humans are more inclined and addicted to computing devices and in particular mobile device. The mobile devices are becoming more robust in terms of computations because of their tremendous increase in their capabilities with the assistance of allied branches like computer networks, Artificial Intelligence and machine learning. Generally Mobile device is controlled by cellular towers presently. As the abilities of mobile devices are increasing it seems that the user has to be given the choice of selecting and opting to the requirements according to his wish. When the user (Mobile device) is moving, the controlling is done by the cellular towers. In this scenario the mobile will have less control, in our next generation mobile device because of robustness and latest configuration the choice of selecting the services which are offered by the cellular towers in the vicinity of the user mobile is decided by the mobile device (user). We call this as User Centric. The device executes Nature Inspired algorithm called Firefly algorithm which is a PSO based algorithm basically to find the best tower that can extend the service which the user requires or specifies and after optimization of algorithm with the given user input parameters switching takes place basing on the outcome of the selection the user mobile device will establish her network connection with the mobile tower and continue with the user specified parameters services till the next type of service is opted by the user mobile device.

**Key words :** Firefly, Nature Inspired Algorithm, PSO, User Centric

## 1. INTRODUCTION

Mobile technologies are evolving with the help of artificial intelligence and machine learning capabilities. The computers or mobile devices are achieving this through programming software supported by machine learning and artificial intelligence based algorithms.

We are taking a new scenario here, in near future we are going to have a situation where the power of computation increases tremendously and most of the gadgets that the humans will use will have similar or equivalent computation power. We have identified that in near future, the requirement that almost all the applications are going to move in the direction of user and basing on his thoughts in accordance the application has to extend her processing. One of such device or gadget is the mobile phone which is smarter, more powerful in terms of computation and more capable of taking decisions.

Such a computing device will have a different perspective of decision making computation basing on the situation and circumstances that it is going to have at a particular instance of time and AI as well as ML aids in choices of the users. This idea has been extended to the mobile devices where service is extended by the mobile towers. In present situation the mobile devices are controlled by the mobile towers which are under the control of the particular cellular company. In near future this controlling capability changes into a different direction called user centric notation because of the capabilities it will achieve in terms of computation. In our defined notation the user, basing on his intended type of service, he will have a greater selection choice about which tower has to extend the service to him.

## 2. NATURE INSPIRED ALGORITHMS

Nature inspired computation is based on the abstractions of the natural processes like computation basing on natural computation models which reflect what is happening in nature. "The Principles of Collective Animal Behaviour" [15] provides a list of primitives which we use to understand algorithms that exploit emergent Behaviour. We can use those for our problem solving and the answer is a lot of such models are available. Some of them are hill climbing/descending, simulated annealing, evolutionary computation, artificial neural networks, and artificial neural immune systems.

Our keen observation about the mother nature revealed that it can give us a more powerful and adaptable solution to our requirement that have taken shape into adapting nature inspired algorithms to our defined problem in particular.

The evolutionary algorithms comes into picture as this is one of the major area where a lot of such research and application has been involved and evolved successfully. The key criteria is “fitness” [16] in all of its related topics.

Swarm Intelligence is a new area to study a relative optimal approach for problem solving [1]. One of the extended literature leads us toward the swarm intelligence and swarm optimization where a flock of species collectively and individually take decisions without much loss to the individual and as well as for group.

A more enriched and further extended concept of swarm intelligence is particle swarm optimization (PSO) [17]. Here particles are in swarms and the greatest advantage is because swam is a group of same species, this give the local optima there by generates the global optima with much speed [2].

One of such particle swarm optimization is the firefly algorithm that has a tremendous potential to find a best possible solutions. This generates an optimized solution for a given problem space.

We have considered firefly algorithm for our problem specification. We thought that firefly algorithm is more suitable for our problem definition and confident that we can get an amicable solution if we apply this algorithm for our problem.

Xin-she Yang developed FA in 2007 and published about this algorithm in 2008[3, 4].The prominent characteristic of this Firefly algorithm called as mimicking or flashing lights. In mid months of a year open areas are the best places to sight Firefly in temperature regions. We can find nearly 2000 variants that express similar characteristic of mimicking flashes.

### 2.1. The Performance of Firefly

The Flashing depends on the type of species with each having an individual pattern and it depends on two fundamental functionalities like, to attract mating partners (communication) and another one is for prey [5]. Flashing acts as a safeguard against other species and to stay away from them and acts as a warning for predators.

The Firefly has an efficient signaling system to communicate that includes flashing rhythmically, the flashing rate and time gap between successive flashes make the other species to come closer[5]. Some of the species use this pattern to attract the male species and become prey for these. The capability of the Firefly in synchronizing the flashes and their self-organized behavior makes them emerging

### 2.2. Standard Firefly Algorithm

We assume that any Firefly (FA) has 3 prominent characters

*1). unisex in nature:* Each of the Fireflies are attracted to one another

*2). Attractiveness:* Attractiveness is proportional to brightness of each one of these moves towards much brighter Fireflies if no such comparative brightness the firefly will move randomly in search of brightest.

*3). Objective function:*The effectiveness, scope of the objective function are determined.

These algorithms are evaluated basing on the fitness function and mapped to the objective function which is attained through a maximization in terms of brightness. Depending on these three regulations the pseudo code for Firefly is

### 2.3. Firefly Algorithm [10]

***Objective function***

f (x), x = (x1, ..., xd)T .
Generate an initial population of n fireflies
xi (i = 1, 2, ..., n).
Light intensity Ii at xi is determined by f (xi).
Define light absorption coefficient γ.
*while (t <MaxGeneration),*
*for i = 1 : n (all n fireflies)*
*for j = 1 : n (all n fireflies) (inner loop)*
*if (Ii <Ij)*
*Move firefly i towards j.*
*end if*
*Vary attractiveness withdistance r via exp [−γr2].*
*Evaluate new solutions andUpdate light intensity.*
*end for j*
*end for i*
*Rank the fireflies and find the current global best g∗.*
*end while*

### 2.4. Variations in Intensity of light and measure of attractiveness

The patterns are different for different species. The light intensity and attractiveness plays a significant role. The assumption that attractiveness is related to brightness and in turn related to objective function.

At a location 'x' Firefly brightness 'I' can be selected as$\boldsymbol{I(x) \alpha f(x).}$

The parameter 'β'represents attractiveness. It is a subjective and relative attribute acts upon the individual Firefly. The absorption co-efficient or degree of absorption of media acts as an additive in formulating the attractiveness. The intensity of light varies with inverse square law

$$I(r) = \frac{I_s}{r^2} \qquad (1)$$

Where Is - is source Intensity?
r - Distance
I – Intensity of Light
'γ' – Absorption co-efficient , Hence

$$I = I_0 e^{-\gamma r} \qquad (2)$$

$\boldsymbol{I_0}$Intensity of light at distance 'r' = 0.

By combining Intensity and absorption basing on Gaussian law

$$I(r) = I_0 e^{-\gamma r^2} \qquad (3)$$

From this above equation attractiveness β can be estimated by

$$\beta = \beta_0 e^{-\gamma r^2} \quad (4)$$

The above equation can be written as

$$\beta = \frac{\beta_0}{1+\gamma r^2} \quad (5)$$

From " (4)" and "(5)"

The characteristic distance $\Gamma = \frac{1}{\sqrt{\gamma}}$

Changes the attractiveness significantly from

$\beta_0$ *to* $\beta_0 e^{-1}$ **for eq (4)**

**or** $\frac{\beta_0}{2}$ **for eq (5)**

In general, monotonically decreasing can be

$$B(r) = \beta_0 e^{\gamma r^m} (m \geq 1) \quad (6)$$

If absorption is constant the distinctive length is

$$\Gamma = \gamma^{-\frac{1}{m}} \to 1 (m \to \infty) \quad (7)$$

Reversely for the problem of optimization usage of 'γ' is represented as

$$\gamma = \frac{1}{r^m} \quad (8)$$

The distance among two Fireflies is the Cartesian distance [6]

$$r_{i\ j} = \left\| x_i - x_j \right\|$$

$$= \sqrt{\sum_{k=1}^{d} (x_{ik} - x_{jk})^2} \quad \textbf{(9)}$$

Can also be written as

$$r_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad \textbf{(10)}$$

The attractiveness can be given by [7]

$$x_i^{t+1} = x_i^t + \beta_0 e^{-\gamma r_{ij}^2} (x_j^t - x_i^t) + \alpha \varepsilon_i^t \textbf{(11)}$$

The original expression is supplement with attractive and absorption co-efficient 2nd and 3rd terms. $'\varepsilon_i'$ Is a random number (Vector) drawn from a Gaussian distribution or uniform - Distribution.

## 3. INPUT PARAMETERS

With this theme of execution we have considered a heterogeneous wireless environment with four types of dissimilar networks such as [11] UMTS, WLAN, and WiMAX. We are considering different parameters as criteria which are named as Packet Delay in ms, Packet Jitter in ms, Packet Loss per each $10^6$ packets, Cost per Byte, Available Bandwidth in Mbps, Received Signal Strength in dB [8]. Various types of technologies like Universal Mobile Telecommunication Services (UMTS) [12], Long Term Evolution (LTE), WLAN [13],and Wireless Max Worldwide Interoperability for Microwave Access (WiMAX) [14] are considered as alternatives.

## 4. ASSUMPTIONS

We have considered the following parameters for evaluation of our problem. The ranges have been typically considered through the literature survey. The parameters and their ranges are mentioned in Table 1.

**Table 1:** Assumed Parameters and Their Values.

| Parameter | | Packet Delay (ms) | Packet Jitter (ms) | Packet Loss (per $10^6$) | Cost per byte (Price) | Available Bandwidth | Received Signal Strength(dB) |
|---|---|---|---|---|---|---|---|
| ALTERNATIVES | UMTS | 39 | 9 | 60 | 9 | 0.1 | -60 |
| | LTE | 30 | 18 | 25 | 25 | 02 | -50 |
| | WLAN | 90 | 50 | 70 | 10 | 60 | -75 |
| | WIMAX | 85 | 15 | 50 | 50 | 40 | -70 |

## 5. ARCHITECTURE WITH USER CENTRIC NOTATION

The problem is defined as follows, Assume that in near future a user is equipped with a mobile device with a robust configuration and latest AI enable tools to assist the user. Now the user has an application let's say he has to send a large file may be in few hundred Gigabytes. So, now he should have an option to send his large file which can be sent only if the mobile tower supports with a huge

bandwidth. So the user(mobile device) tries to search in her vicinity which tower has that capability of sending large file with a good bandwidth with a search procedure basing on the search outcome it will select that tower which is best among all the towers around her. Now it connects to that tower to send the large GB file with a much ease.

In our user centric theme, user is prompted with the choices of selecting the type of the parameter that he currently wishes to apply. Once this parameter is selected the process will prompt for the selection of technology of the tower around the mobile. Upon taking the two input parameters the program uses the firefly algorithm to find the best tower that can extend her service in accordance with the user inputs. If algorithm execution result matches with the user input parameters of technology among UMTS, LTE, WLAN, WiMAX, it will serve according to the user wish. Most of the times finding the best tower with the algorithms and finding best choice as per the execution of the algorithm may not match with the user specification at such times it will prompt the user that the current user requirement will not give an optimized outcome and switches to send the file as per her executed program best tower selection as outcome. The sending of the large file with a good bandwidth is executed and the file will be transferred successfully. The choice of selecting the tower depends on the required parameter that mobile or the user of the mobile opts. Basing on the evaluated criteria and final decision user mobile selects the best tower for her further execution.

We tried to execute this scenario in Matlab. As the simulated environment is dealing with a highly dynamic changing scenario where the signals and towers are switching frequently. We tried to collect information about those towers which are newly added to the existing towers as one case and even some of the towers may stop serving the user, we maintained such information in another matrix for such towers and we have limited the towers failures to one from each technology (alternative).

We calculated the best cost and that best cost is taken as a tower according to the specified parameters of the user.

We tried to calculate with different combinations as use cases and finally we tried to simulate the best cost scenario irrespective of user choice both in terms of parameter criteria as well as alternative choice of technology.

## 6. MATLAB EXECUTION USING USER CENTRIC NOTATION

Typically we have taken two mathematical functions for our evaluation. They are Sphere function and Rosenbrock function. We tried to implement with a range of [-50,150] [8]. The considered parameters [8] are six namely

1. Packet Delay,
2. Packet Jitter,
3. Packet Loss,
4. Cost per Byte,
5. Available Bandwidth,
6. Received Signal Strength.

We have initialized the population size of fireflies as 20. Basing on the number of parameters (6), range values of those parameters [-50,150] and number of iterations is 100. We tried to execute the firefly algorithm with the defined function to find the best cost that leads to the optimization of the fireflies under user centric notation.

We have applied the said values for the attraction equation that was defined in the literature of firefly's algorithm which is as follows

$$NewX = X + \beta_0 e^{-\gamma r^m}(Y - X) + \alpha \varepsilon_i$$

Where **'$\beta_0$'** is the attractiveness at the source point. This co-efficient should be selected specially for your specific problem. According to the firefly algorithm documentation for most of the optimization problems considering **'$\beta_0$'** =1 works well. Here **'γ'** is the absorption co-efficient. In theory **'γ'** can be any value however it is recommended to consider co-efficient value between 1 and 10. Selecting an appropriate **'γ'** amount increases convergence speed of your model. So that for each specific problem different amounts of this co-efficient should be examined. Another co-efficient for this equation is **'m'.** As we know 'm' = 2 because fireflies are spotlight sources. As we mentioned according to our problem we can consider any amount bigger or equal to one(1).we considered this variable as **'m' = 2** works perfectly. Another co-efficient of this equation is 'r'. 'r' is the Cartesian distance between fireflies 'x' and 'y'. As we know this 2-Dimentional example 'r' is calculated using this equation. Here**'α'** is the randomization parameter that shows the in terms of random movement. **'□ᵢ '. '□ᵢ 'is** the vector that comprises random elements that could be generated according to the Gaussian or uniform distributions. Hence this is the final equation in order to calculate the movement of firefly towards another firefly. After defining the firefly movement's equation mathematically.

The values that are considers for this equation parameters are as follows

Beta = 1, Gamma = 1, Alpha = 0.2, m = 2.

We are using particle swarm optimization for solving our problem of user centric notation using firefly algorithm from nature inspired algorithms. Our algorithm is implemented using the Matlab. We have used optimization toolbox for the usage of mathematical functions like Sphere and Rosenbrock [9]. In the Matlab program we are considering or requesting the mobile device (user) about the inputs and basing on the user inputs the analysis is performed by the firefly algorithm for an optimized best cost.We have taken case by case of execution with parameters (Criteria) and alternatives.

## 7. GENERATED GRAPHS

We have generated graphs which is best cost graph after completion of the specified no of iterations. We have generated another graph which reflects the first four best cost towers as a graph so for every parameter that we take will generate two graphs. There are six parameters that we

have considered hence generates twelve graphs for 'Rosenbrock' and another twelve graphs for 'Sphere'.We tried to execute the fitness function "*Rosenbrock*" function for the optimization. The graphs are generated as follows.

For the input Bandwidth as parameter and UMTS as the tower the graphs that are generated one graph for best cost and another graph for first four best costs as shown in Figure 1a and Figure 1b.

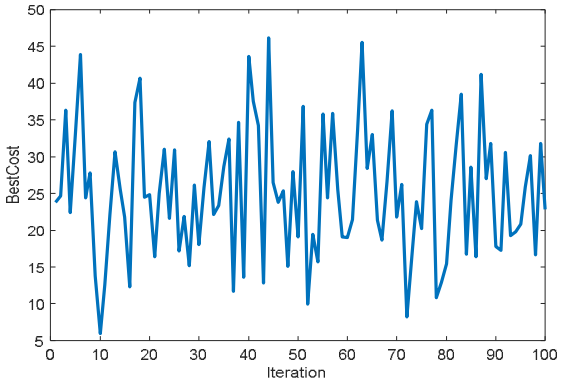


**Figure 1a**: Best Cost in terms of Bandwidth & UMTS

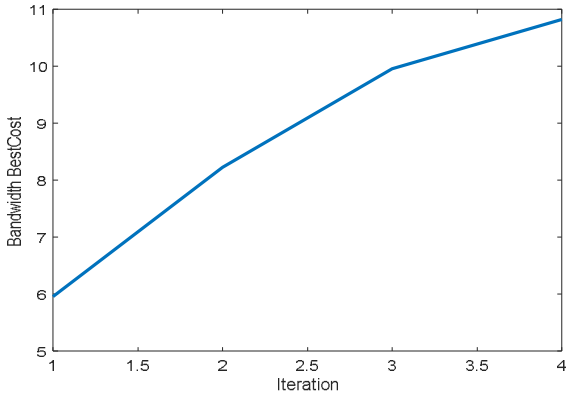


**Figure 1b:** First Four BestCost in terms of Bandwidth & UMTS

For the input Packet Loss as parameter and LTE as the tower the graphs that are generated one graph for best cost and another graph for first four best costs as shown in Figure 2a and Figure 2b.

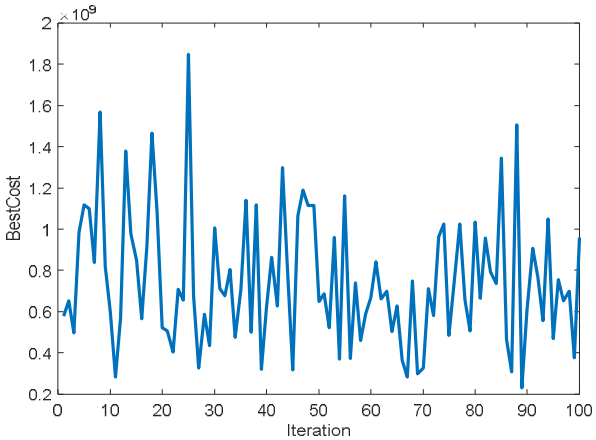


**Figure 2a:** Best Cost in terms of Packet Loss & LTE

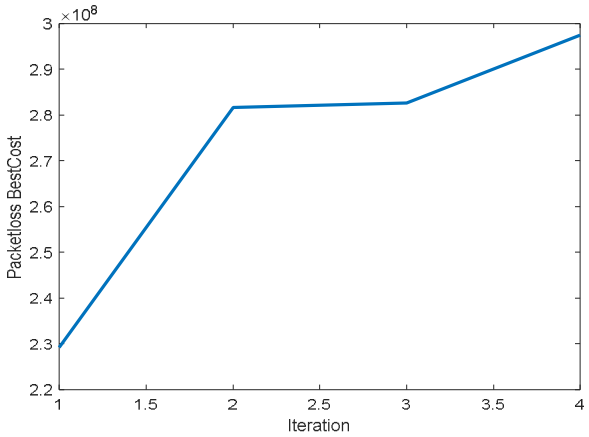


**Figure 2b:** First Four Best Cost in terms of Packet Loss & LTE

For the input Packet Delay as parameter and WLAN as the tower the graphs that are generated one graph for best cost and another graph for first four best costs as shown in Figure 3a and Figure 3b.

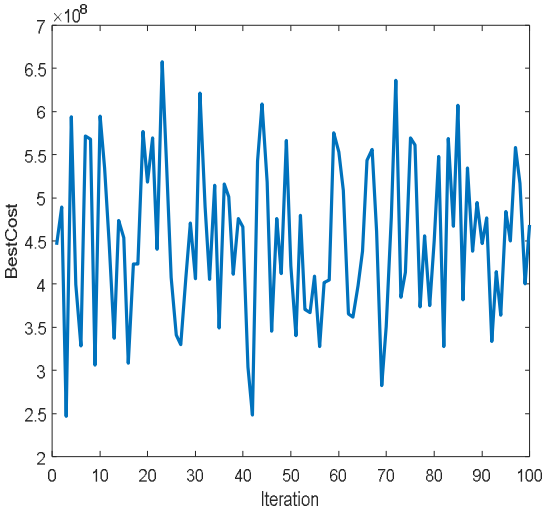


**Figure 3a:** Best Cost in terms of Packet Delay& WLAN

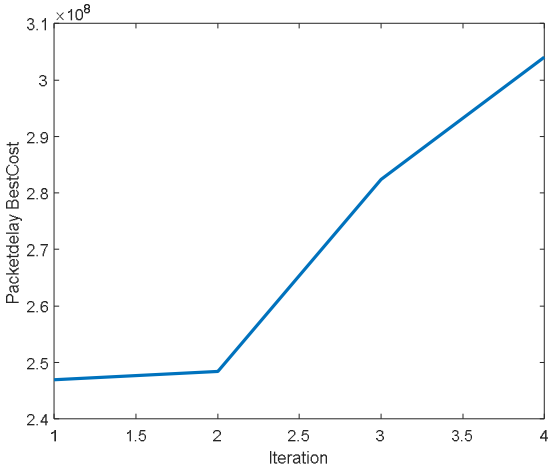


**Figure 3b**: First Four Best Cost in terms of Packet Delay & WLAN

For the input Packet Jitter as parameter and WIMAX as the tower the graphs that are generated one graph for best cost and another graph for first four best costs as shown in Figure 4a and Figure 4b.

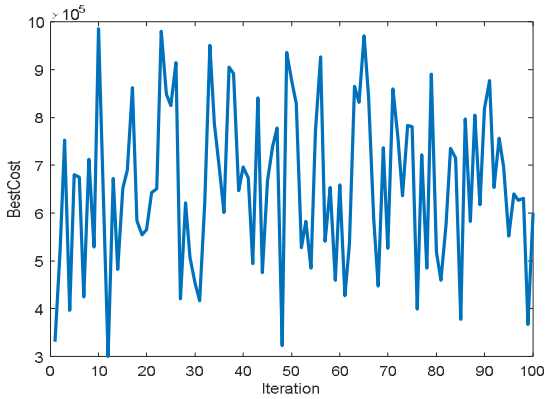


**Figure 4a:** Best Cost in terms of Packet Jitter& WIMAX

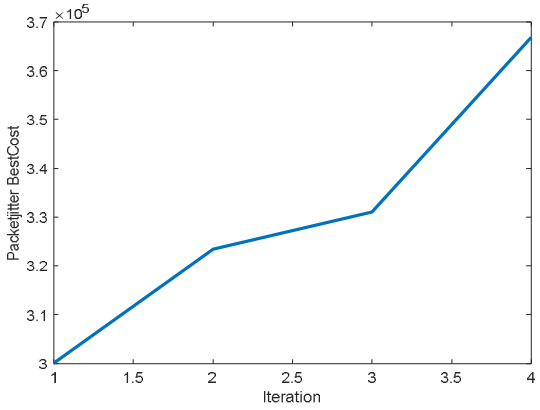


**Figure 4b:** First Four Best Cost in terms of Packet Jitter & WIMAX

For the input Received Signal Strength as parameter and LTE as the tower the graphs that are generated one graph for best cost and another graph for first four best costs as shown in Figure 5a and Figure 5b.

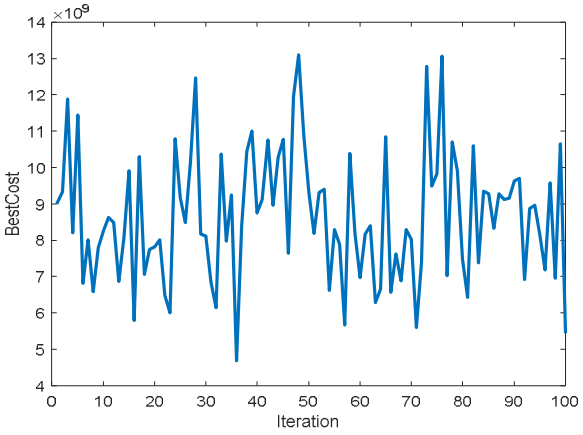


**Figure 5a:** Best Cost in terms of Received Signal Strength & LTE

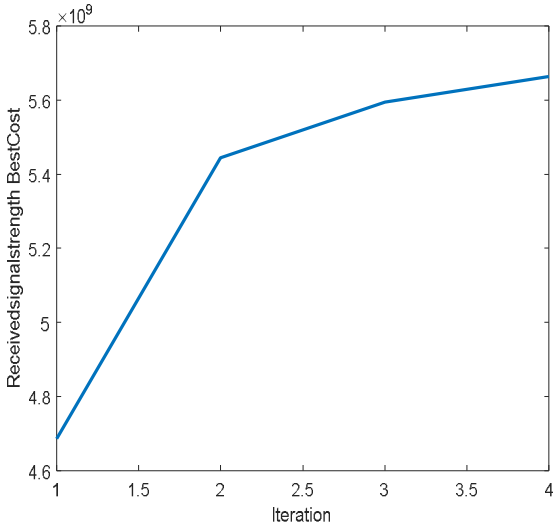


**Figure 5b:** First Four Best Cost in terms of Received Signal Strength& LTE

For the input Cost per Byte as parameter and WLAN as the tower the graphs that are generated one graph for best cost and another graph for first four best costs as shown in Figure 6a and Figure 6b.

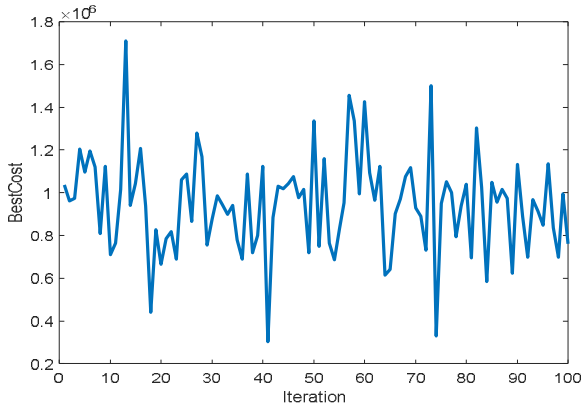


**Figure 6a:** Best Cost in terms Of Cost per Byte & WLAN

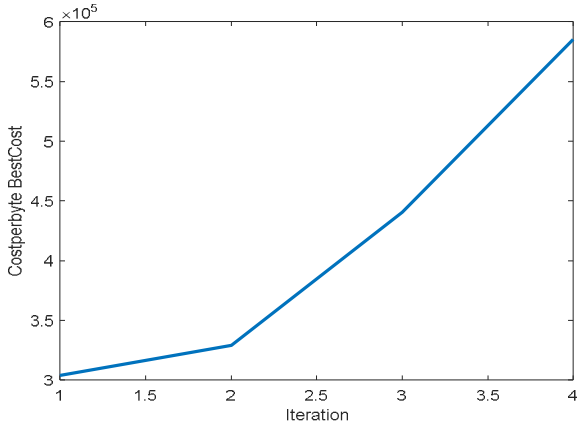


**Figure 6b:** First Four Best Cost in terms of Cost per Byte & WLAN

We tried to execute another fitness function "Sphere" function for the optimization. The graphs are generated as follows.

For the input Bandwidth as parameter and UMTS as the tower the graphs that are generated one graph for best cost and another graph for first four best costs as shown in Figure 7a and Figure 7b.

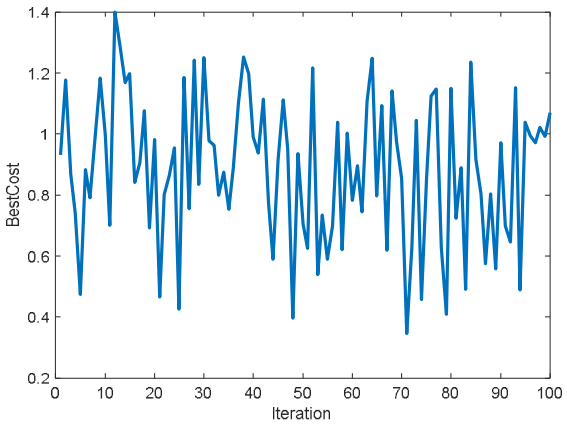


**Figure 7a:** Best Cost in terms of Bandwidth & UMTS

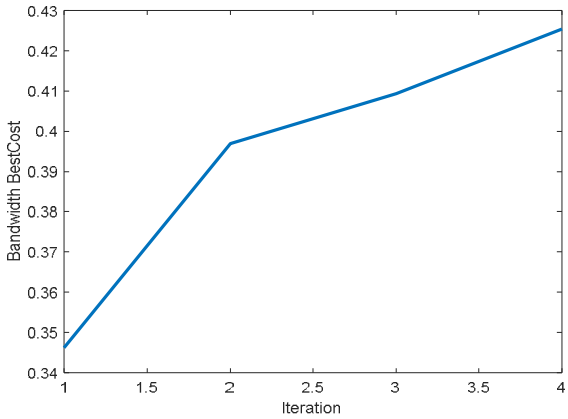


**Figure 7b:** First Four Best Cost in terms of Bandwidth & UMTS

For the input Packet Loss as parameter and LTE as the tower the graphs that are generated one graph for best cost and another graph for first four best costs as shown in Figure 8a and Figure 8b.

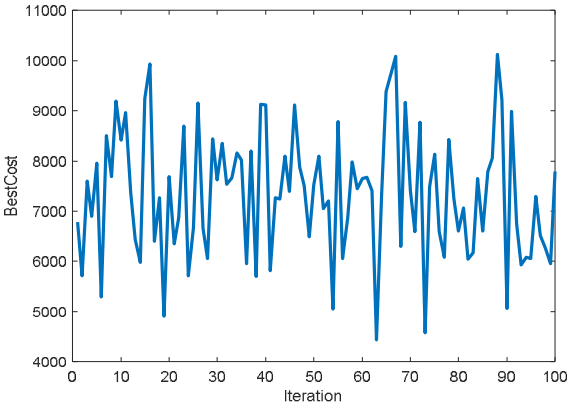


**Figure 8a:** Best Cost in terms of Packet Loss & LTE

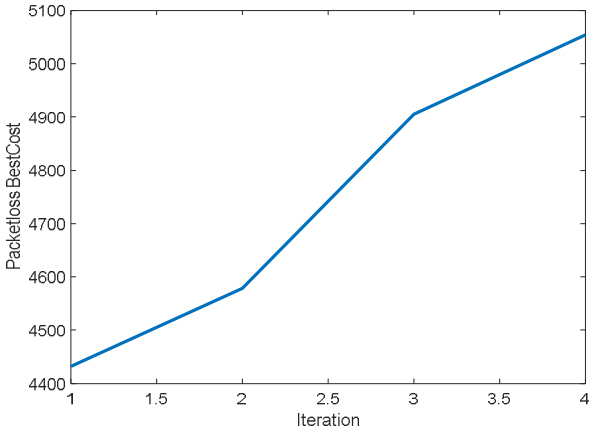


**Figure 8b:** First Four Best Cost in terms of Packet Loss & LTE

For the input Packet Delay as parameter and WLAN as the tower the graphs that are generated one graph for best cost and another graph for first four best costs as shown in Figure 9a and Figure 9b.

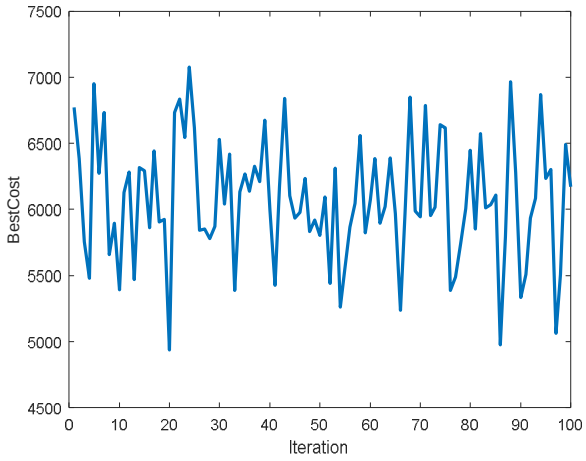


**Figure 9a:** Best Cost in terms of Packet Delay & WLAN

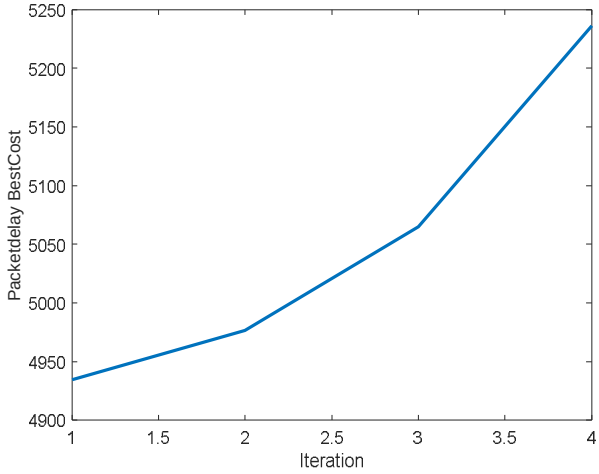


**Figure 9b**: First Four Best Cost in terms of Packet Delay & WLAN

For the input Packet Jitter as parameter and WIMAX as the tower the graphs that are generated one graph for best cost and another graph for first four best costs as shown in Figure 10a and Figure 10b.

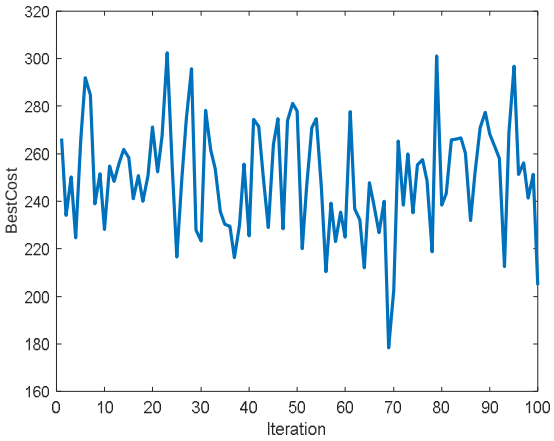


**Figure 10a:** Best Cost in terms of Packet Jitter & WIMAX

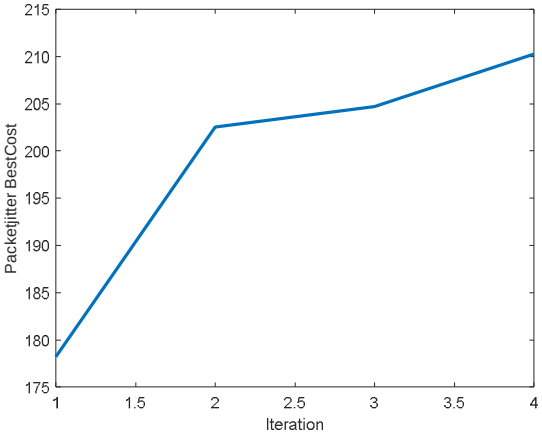


**Figure 10b:** First Four Best Cost in terms of Packet Jitter & WIMAX

For the input Received Signal Strength as parameter and LTE as the tower the graphs that are generated one graph for best cost and another graph for first four best costs as shown in Figure 11a and Figure 11b.

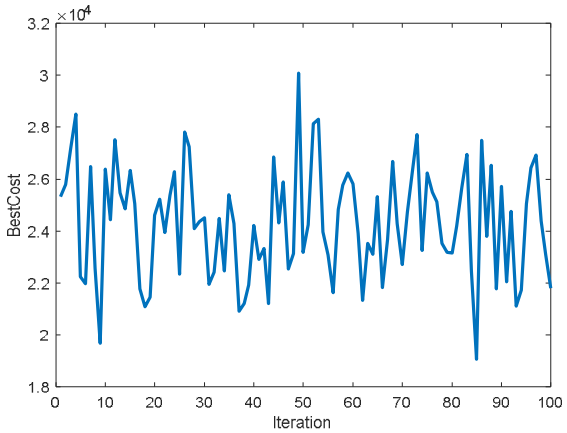


**Figure 11a:** Best Cost in terms of Received Signal Strength & LTE

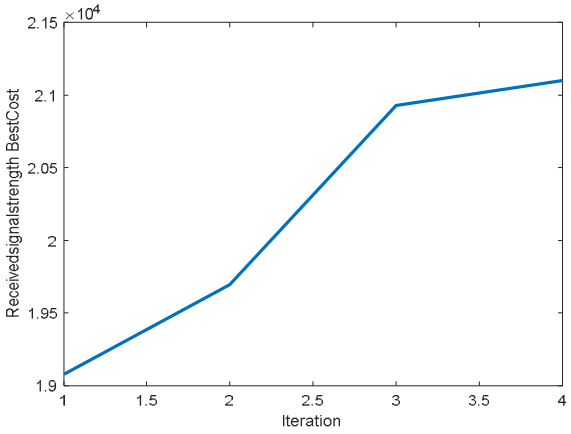


Figure 11b: First Four Best Cost in terms of Received Signal Strength& LTE

For the input Cost per Byte as parameter and WLAN as the tower the graphs that are generated one graph for best cost and another graph for first four best costs as shown in Figure 12a and Figure 12b.

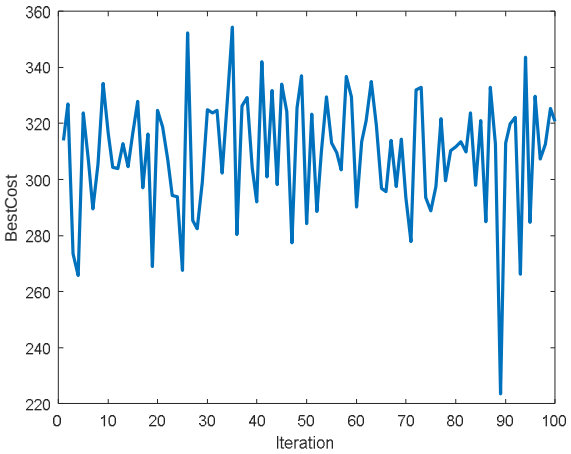


**Figure 12a**: Best Cost in terms Of Cost per Byte & WLAN

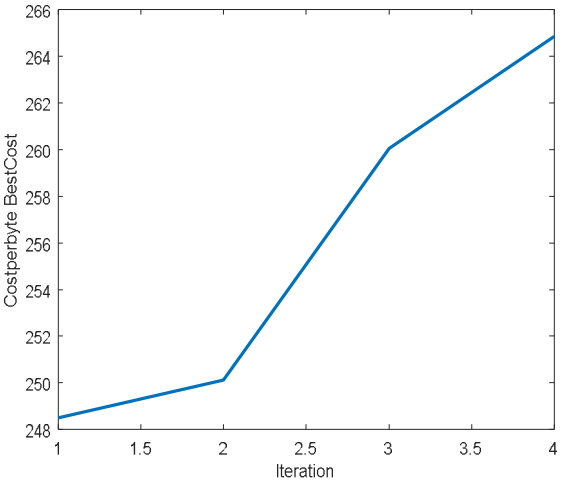


**Figure 12b:** First Four Best Cost in terms of Cost per Byte & WLAN

## 8. CONCLUSION

From the results we conclude that we have tried to simulate with various criteria parameters like Packet Delay, Packet Jitter,Packet Loss, Cost per Byte, Available Bandwidth, Received Signal Strength and alternatives like UMTS, LTE, WLAN, WiMAX and the results are matching with the literature. We can even further optimize these values if we consider more number of iterations along with increasing the swarm size. One can fine tune outcomes by varying Beta, Gamma, & Alpha. For future research we will make effort on using more generalization of the execution along with multi criteria decision making algorithms to evaluate and compare these parameters to further strengthen this idea. One can extend this research to have a security module for authentication and encryption of the transmitted data and power aware computing for mobile devices [18].

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