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Optimization of facility location-allocation model for base transceiver station antenna establishment based on genetic algorithm considering network effectiveness criteria (case study north of Kermanshah)

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Abstract. The location of Base Transceiver Station (BTS) antennas plays an important role in the proper serviceability and coverage of mobile connections in each region. Finding a proper location for these antennas is a major challenge for operators in each country, as service costs besides maximum network coverage must be acceptable and competitive. This means that in busy areas, in order to provide better service, the antennas must be larger in size and positioned closer to each other. In general, the location problem is a type of optimization problem that aims to select a subset of candidate locations to create facilities that provide the best service at the lowest cost. To solve such problems in a reasonable span of time, we can use meta-heuristic algorithms to find solutions that are close to the optimal solution. Accordingly, this paper attempts to apply the Genetic Algorithm (GA) to find a suitable solution for finding BTS mobile antennas in north Kermanshah. To this end, a GA model is proposed that improves the location coordinates of the current BTS antennas extracted from the Geographic Information System (GIS). Comparison of model results with the status of BTS active antennas in Kermanshah shows the performance of the model.

1. Introduction

The human need for telecommunication services has been on the rise in the information age. Telecommunication companies (Telcos) continue to improve and develop their technologies and services, as well. However, even with the fast development and invention of telecommunications technologies, the process of adopting such technologies in Telcos is not immune from emerging problems, particularly those related to the connection interference experienced by customers [1].

Base Transceiver Station (BTS) as an auxiliary signal generator is used for cellular purposes. The role of BTS is integral in facilitating data exchange activities such as web browsing and others. To optimize the smooth communication of data through BTS, the use of spatial data is essential. With spatial data, cellular network development such as new BTS development can be considered and plotted. The position of a BTS has been calculated based on the range of

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the transmitted signals. The number of base stations in urban areas is larger than in rural areas because each operator desires full signal coverage so that it can attract consumers to use their system [2].

The problem of facility location is a branch of operations research that attaches great significance to both practical and combinatorial optimization perspectives. The classical location problem was concerned with determining the location of a facility to optimize facility allocation to customers [3].

BTS mobile telecommunication stations continue to be a popular part of the mobile telecommunications service network for over a decade. However, their establishment as elements featuring specific characteristics and physical dimensions has given rise to negative consequences for urban areas. The severity of these consequences is much greater than expected due to the non-observance of the principles and rules of urban planning, as well as a lack of consideration in this regard [4].

The installation location of BTS telecommunication antennas plays a very important role in servicing and providing appropriate coverage in the areas concerned. Meanwhile, the study of the distribution of waves in urban environments is one of the major issues in designing a mobile telecommunication network.

Service availability is an objective pursued by operators offering various systems and services that vary with respect to the development of cellular radio network infrastructure, including the number and location of BTS towers, which is a compulsory requirement. Viewed from the opposite viewpoint, the high density of tower locations can cause problems that affect the community. On the one hand, the increasing number of tower sites will indeed facilitate meeting the community's need for telecommunication services. On the other hand, a non-coordinated development will disrupt the beauty of the region [5].

The deployment of many BTSs by different telecommunication operators, scattered all over the vicinity of residence, work, and schools, has become a great concern due to not only economic reasons but also exposure to radiation by the general public within the BTS environment [6]. In fact, the quality of wireless communications depends on many conditions in that area. Without taking these conditions into consideration, designing an optimal communication network for mobile telecommunications can be challenging, if not impossible.

The number of BTSs continues to increase in response to the growing demand for communication. In this way, customer needs are met and the best service can be provided. To ensure optimal signal quality in the BTS network, mobile operators must continuously monitor and support it. Therefore, an application is needed to find the shortest BTS to run on the android platform so that it can help technicians optimize the distance to the location of the station in case of damage and maintenance [7].

Therefore, correct locating of BTS antennas is a type of non-deterministic polynomial-time hard (NP-HARD) problem; in this regard, the complexity and volume of computational problems increase exponentially by the increase in the number of demand points and service centers. In general, the issue of facility locating is an optimization problem that aims to select a subset from a set of candidate locations to provide facilities that offer the best service at the lowest cost [8].

Currently, conventional methods are used to locate BTS mobile antennas based on the technical and legal standards approved by the Ministry of Communications and Information Technology [9]. In many cases, the quality of service in an area is not acceptable due to the poor initial location; to resolve this issue, the number of stations must be increased, which is accompanied by ultimate rise in the costs and number of installation problems.

In order to solve problems, Genetic Algorithm (GA) generates a set of possible solutions. Each of these solutions is evaluated using a fit function. Then, new solutions are created using three operators: selection, intersection, and mutation. This will evolve the solutions. Hence, the search space evolves in a direction that achieves the optimal solution.

The proposed method represents a significant advancement in the problem of locating BTS mobile antennas and the subsequent intelligent optimization of their placement. The application of this approach successfully reduces the number of towers, decreases related operational costs, and enhances communication service quality compared to conventional methods.

The main objective of this study is to determine the coordinates of the proposed points to establish BTS antennas based on the network performance criteria and the GA (a case study of the north Kermanshah), with proper performance compared to the existing traditional methods.

2. The review of the related literature

2.1. Base Transceiver Station (BTS)

Basically, a telecommunication system requires equipment and devices that transfer and receive information (transceivers) using electronic codes that rely on radio frequency [10].

The first part that is directly connected to the mobile phone in the mobile network is generally called "mobile antenna" and BTS in particular.

BTS are a critical component of the Global System for Mobile (GSM) network, and they are ubiquitous in the areas covered by the network, with a large number of them visible almost everywhere. In fact, the network is often identified by the BTSs. These stations communicate with each other through direct aerial vision by microwaves, forming an integrated network and providing subscriber communications.

BTS is a transceiver and acts as an interface between the Mobile Stations (MS) and the network. A BTS will have between 1 and 16 Transceivers (TRX), depending on the geography and demand for service of an area. Each TRX represents one Absolute Radio Frequency Channel Number (ARFCN). However, the number of sectors a BTS can host and the cell coverage may vary depending on geography, service demand, and the network strategy and architecture of the operator. A BTS may host up to two, three, or six sectors, or a cell may be serviced by multiple BTSs with redundant sector coverage. In each sector, a directional antenna known as a sector antenna is used to provide coverage [11]. The main tasks of BTS are given below [12]:

- Organizing common radio channels in a cell, in which the channel request is received from the MS and sent by BSC to allocate, if possible, a channel to the MS. It also disables the channel and initiates encryption;
- Encoding the information received from BSC to send to the MS, decrypting the information received from the MS and sending it to BSC, and multiplying the logical channels and sending them to the physical channels;
- Controlling radio subsets, which include setting the time required for sending information by the MS which is regularly updated and sending the results to the BSC;
- Sending the output power control signal to MS to reduce interference and optimize the MS power;
- Sending information to many units and receiving the corresponding microwaves;
- Synchronizing the required information from Pulse Code Modulation (PCM) link and replacing the number of frames with the counter in it;
- Setting frequency parameters, output power of transmitters, and receiver frequencies, as well as BTS color code.

Each BTS contains the following modules:

- A. Transceiver Interfaces (TRI): BTSs are used consecutively for connections, in which case the control information related to the second BTS is sent;
- B. Transceivers (TRX): Each TRX in the binary mode can serve 8 subscribers on eight temporal gateways. Depending on the location of the site, their number can be determined. For instance, up to 6 TRXs are introduced for any sites in crowded areas of each sector. Basically, each site has 3 sectors in three different directions, and each sector has 6 TRXs. Therefore, its capacity is displayed as 6 + 6 + 6;
- C. Local storage terminal;
- D. Transceiver Interfaces Input/Output (TRI I/O) terminal;
- E. Basic band switch: It determines the order of system's communication with different image receivers;
- F. Timing: It extracts a base frequency from CLICK of PCM line to generate carriers, transmitters, and receivers as well as counts Time Division Multiple Access (TDMA) frames accurately;
- G. Transmitter mixer: It mixes signals from TRX and sends them to the antenna;
- H. Divider: Strengthening and dividing received waves involve enhancing and amplifying the signals received from antennas and divide them;
- I. Power converter: A converter inside the BTS can convert Voltages Alternating Converted (VAC) 220 or Voltages Directly Converted (VDC) 66-48 into the VDC 24 voltage required for the BTS power supply.

In the case of the first competitive facility location model for the cognitive radio network, it is assumed that each customer patronizes the company with the best signal quality from its nearest base station. Each customer makes their own decision independently, similar to the case of most facility location models. This study proposes a new model for customer behavior. We assume that customers are mobile. They experience and evaluate the quality of connection over the whole network. Thus, the company (mobile operator) is selected based on the average quality of service. In other words, we assume that customers can move from one operator to another until the average quality of service will be the same and they reach the Nash equilibrium [13].

2.2. GA procedure

GA as an optimization computational algorithm, taking into account a set of solutions for spots in each computational repetition, efficiently searches for different areas of the solution space. In the search mechanism, although the value of the objective function of the entire solution space is not computed, the calculated value of the objective function for each point plays a role in the averaging of the target function in all subspaces on which that point is dependent. These subspaces are statistically averaged in terms of objective function in a parallel manner. This mechanism is called implicit parallelism [14].

This process involves searching the space in the regions where the statistical average of the target function is high and the possibility of an absolute optimal point in them is greater, because, unlike the single-way methods, the solution space is searched comprehensively in this method and the probability of convergence to a local optimal point is low.

In 2008, Calleja and Debono presented a method for position detection based on pattern recognition using important parameters in a mobile signal by using a database of information sensitive to locations in the area under study; they concluded that the release of multiple routes would not reduce the precision of its location estimation [15].

Munene and Kiema conducted a case study in Nairobi, Kenya, where they used Geographic Information System (GIS) to locate BTS antennas. Their findings suggested that the use of a GIS database could greatly facilitate the process of locating BTS antennas [16].

In 2012, Alamur et al. proposed a method based on GA employed to capture the radio frequency of mobile networks and determine the location of the central station. This method involves using a specific type of inter-section operation in the GA to obtain better solutions [17].

3. Research methods

The present study adopts an empirical-applied approach in line with its application. The topographical map of Kermanshah city, originally at a scale of 1/25000, was processed by the city's natural resources office. Additionally, the city neighborhood map was processed by the municipality of Kermanshah, according to the Research Institute of the World (2015). Required information was obtained through field surveys, consultation with experts, and data base production [18,19].

North of Kermanshah, which is our case study, is characterized by coordinates ranging from 47 degrees and 08 minutes to 47 degrees and 19 minutes, east and 35 minutes to 34 degrees and 38 minutes, north.

In order to apply GA to optimize the number of installed antennas, we must first add their coordinates to the algorithm and then, employ the MATrix LABoratory (MATLAB) simulator to optimize them. In this study, the GIS system was utilized and the information required by the system was added to the system, as well. Mean-while, the exact location was obtained according to the field information (interview and observation), and the final coordinates of the antennas were obtained. Eventually, these coordinates were incorporated into the GA and the final locating process was conducted.

Many studies have been carried out to examine various criteria for choosing a proper location where BTS antennas can be installed, and the following tables present these criteria along with their sub-criteria.

3.1. Technical telecommunication criteria

This group of criteria includes parameters related to the telecommunication operation of the station. The quality of a network is highly dependent on all technical considerations and criteria given in Table 1.

3.2. Construction and installation criteria

This category includes the parameters that ensure the functionality of the station. Depending on the type and model of the station to be installed in the desired location and in view of the equipment to be installed on the site, it is necessary to allow the equipment to be transferred and installed on the site (Table 2).

3.3. Legal and ownership criteria

Neighbors and residents of the area may sometimes disagree on the harmfulness of magnetic radiation due to radiation from the antenna and continue to implement equipment installation. Accordingly, the following criteria are taken into account when receiving eligible candidates by location of groups (Table 3).

3.4. Urban criteria

This category includes criteria relevant to the social

Table 1. Technical telecommunication criteria.

Criterion	Sub-criteria	Description
Technical telecommunication	Capacity	Demand determined based on population density
	Coverage	The area under coverage and the coverable areas specified
	Service level	Traffic congestion and whether the system allowed to block several percentages of subscriber calls
	Service quality	How much the implementation quality of the system is?
	Expansion ability	Prospects for future projects and the development plan in the preliminary design

Table 2. Construction and installation criteria.

Criterion	Sub-criteria	Desctiption
Construction and installation	Enough space to deploy equipment	Availability of sufficient space to deploy equipment and predict the space needed for potential development
	Power supply	Whether it is possible to use urban power supply and if not, it is possible to use emergency electricity for power supply
	Ground strength	Checking the required location for strength
	Cost	Considering the cost of installing the antenna

Table 3. Legal and ownership criteria.

Criterion	Sub-criteria	Description
Legal and ownership criteria	The possibility of signing contracts	The satisfaction of the owner or the owners and the possibility to sign contracts are reviewed
	The lack of ownership and legal problem	The location is carefully considered in terms of lack of ownership and legal problems
	Ownership costs	The costs of ownership including buying or renting should be considered

Table 4. Urban criteria.

Criterion	Sub-criteria	Description
Urban	Sensitive points	Sensitive points such as hospitals, gyms, and military centers are considered
	Traffic	Traffic of the target area is evaluated
	Communication paths	Important paths are taken into consideration

context of the area and they vary in different locations (Table 4).

The application of the analytical hierarchy process contains three basic steps, along with the GIS for locating. In the first step, to achieve the professed goal, the necessary criteria and sub-criteria are formulated, previously presented in the form of tables.

The obtained criteria and sub-criteria are weighed in the second step. To determine the coefficient of significance (weight), the criteria and sub criteria are compared in pairs; then, these significant coefficients are considered in the binary comparison matrix. By using the approximate geometric mean, the coefficients of significance of the criteria were obtained, equal to the division of the geometric mean of each parameter by the sum of the averages.

Delphi method was employed to determine the weights of the criteria and sub criteria. Thus, based on the views of urban experts, weights of criteria and sub criteria were obtained and compared with each other; then, the final weight of each criterion was calculated using Excel software and the geometric mean method. After calculating the final weight of each of the three criteria, the weights of the sub criteria were calculated (Table 5).

4. Results

4.1. Technical telecommunication criteria

After reviewing all the technical and logical sub-criteria using the binary comparison, these values were obtained (Table 6).

As the numbers in the table show, “capacity” as a sub-criterion has the highest impact among other criteria in the same category. This indicates “population density” or in other words “call demand” in an area, which is considered a very important parameter in choosing the place to install the BTS antenna.

By recording the results obtained for each of the sub-criteria in Table 6 in a separate layer of the GIS map of the region and finally by placing these layers on top of each other, the final prioritized map in three levels of importance for the index technical and telecommunication is obtained (Figure 1).

Table 5. The binary comparison of the criteria and determination of significant coefficients (weight).

The main criteria	Technical telecommunication	Construction and installation	Legal and ownership	Urban	Geometric mean	The weight
Technical telecommunication	1	7	5	3	3.20	0.54
Construction and installation	0.14	1	0.33	0.20	0.41	0.07
Legal and ownership	0.20	3	1	0.20	0.59	0.10
Uurban	0.33	5	5	1	1.7	0.29
Total					5.9	1

Table 6. The binary comparison of technical telecommunication sub-criteria.

Row	Capacity	Cover	Service level	Services quality	Expandability	Geometric mean	Standard weight	Original weight
Capacity	1	3	5	3	7	3.15	0.50	0.270
Coverage	0.33	1	3	3	5	1.1	0.17	0.0950
Service level	0.20	0.33	1	0.33	5	0.64	0.10	0.0560
Service quality	0.33	0.33	3	1	3	1	0.16	0.0890
Expandability	0.14	0.20	0.20	0.33	1	0.29	0.046	0.0264
Total						6.18	1	0.54

Figure 1. Integration of sub-criteria and determination of priority criteria for construction and installation.

4.2. The construction and installation criteria

The following table is obtained after reviewing all of the sub criteria for construction and installation using the binary comparison of the values (Table 7).

As it is observed, costs have the most impact on construction and installation criterion, indicating that the cost of installing the antenna is a very important parameter in choosing the location of the BTS.

The sub-criteria were achieved, by using Table 7 and integrating the information obtained from GIS, along with each of the maps, as separate layers placed on top of each other. The combination of these information layers led to the extraction of a prioritized map (Figure 2) that includes three levels of prioritization.

4.3. Examination of legal and ownership criteria

Due to the similar legal and ownership conditions in all regions, the only sub-criterion that varies among different areas is associated with the ownership cost, as is shown in Table 8.

Given that there is no integration of layers in this criterion and there is only one separate map, the same map is placed as the outlined map. The priority of the legal and property measures is given below (Figure 3).

4.4. The examination of the urban criteria

According to Table 9, the sub-criterion namely 'sensitive points' appears to have the greatest impact and the

Table 7. The binary comparison of construction and installation sub-criteria.

Row	Enough space to establish equipment	Round strength	Power supply	Costs	Geometric mean	Standard weight	Original weight
Enough space to establish equipment	1	0.33	0.20	0.20	0.33	0.068	0.005
Ground strength	3	1	0.20	0.33	0.20	0.041	0.003
Power supply	5	5	1	33	1.70	0.35	0.0245
Costs	5	3	3	1	2.6	0.54	0.038
Total					4.84	1	0.07

Table 8. The binary comparison of legal and ownership sub-criteria.

Row	The possibility of contracting	The lack of legal and ownership problems	Ownership costs	Geometric mean	Standard weight	Original weight
The possibility of contracting	1	1	0.2	0.58	0.14	0.014
The lack of legal and ownership problems	1	1	0.2	0.58	0.14	0.014
Ownership costs	5	5	1	2.92	0.72	0.072
Total				4.09	1	0.1

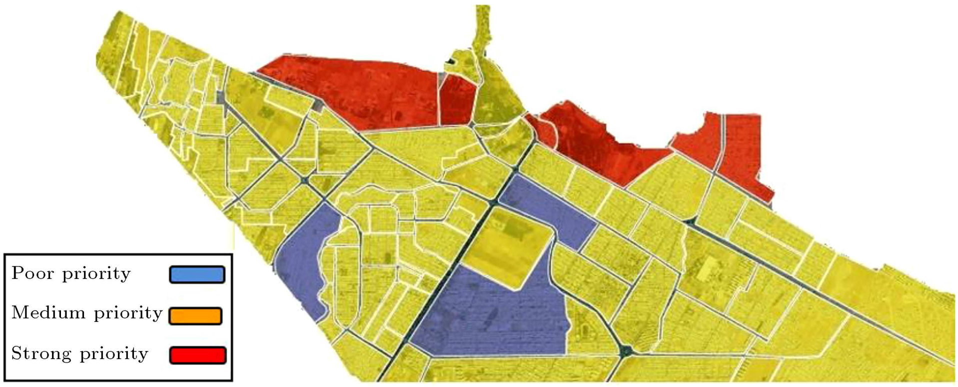

Figure 2. Integration of sub-criteria and determination of priority criteria for construction and installation.

significance of sensitive areas and the military locations draws much attention in this regard.

The mapping of urban priorities is achieved by considering the three parameters, extracting three separate maps using GIS software, and integrating them, as depicted in Figure 4.

4.5. Final integration and identification of the proposed locations

In this stage, upon combining the layers of the main criteria with each other, the prioritization map of the separate areas is obtained. The following chart shows the effect of sub-criteria on the finalized in percent unit (Figure 5). Therefore, based on this chart, the proposed coordinates were obtained and applied to the GA in the north of Kermanshah (Figure 6).

Given these locations, it is clear that areas of higher priority have been nominated for antenna installation. The GIS has calculated the values of all the parameters considered in this selection with different properties and the desired location.

4.6. Comparison of proposed coordinates with existing antenna installation locations

Nowadays, in the northern part of Kermanshah, there are 32 BTS antennas installed in different regions and

Table 9. The binary comparison of urban criteria.

Row	Sensitive points	Traffic	Communication paths	Geometric mean	Standard weight	Original weight
Sensitive points	1	7	5	3.27	0.73	0.21
Traffic	0.14	1	0.33	0.36	0.08	0.024
Communication paths	0.20	3	1	0.84	0.19	0.056
Total				4.50	1	0.29

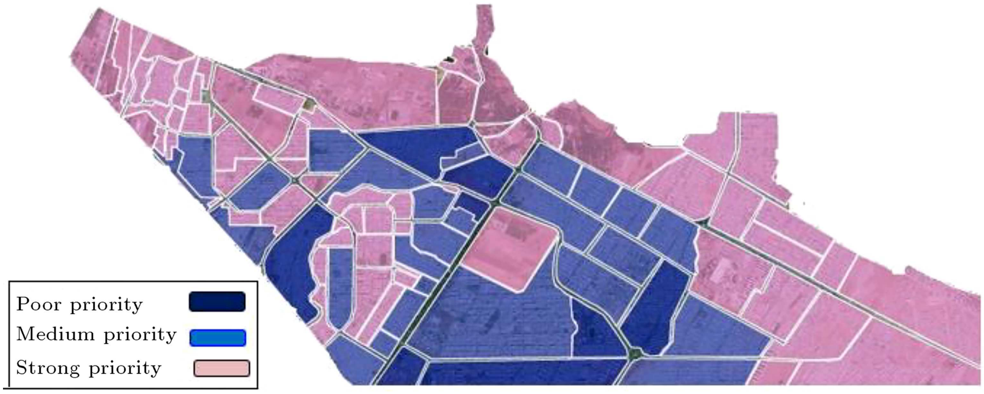

Figure 3. Identification of legal and ownership priorities.

Figure 4. Determination of urban priorities.

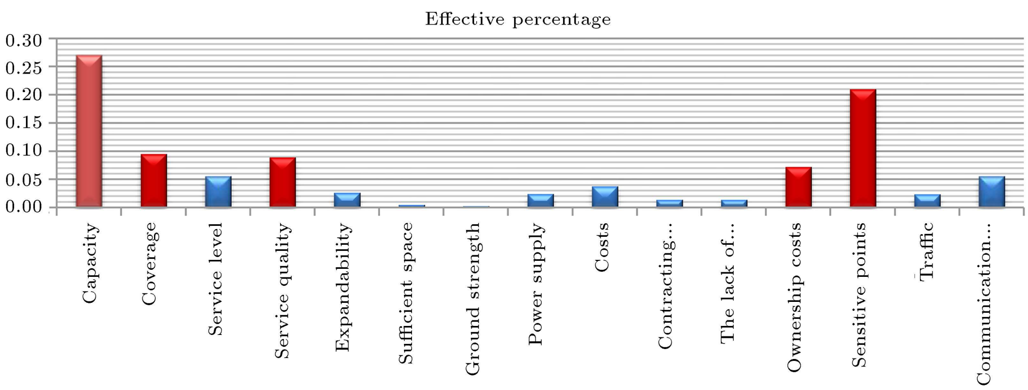

Figure 5. The effects of sub-criteria.

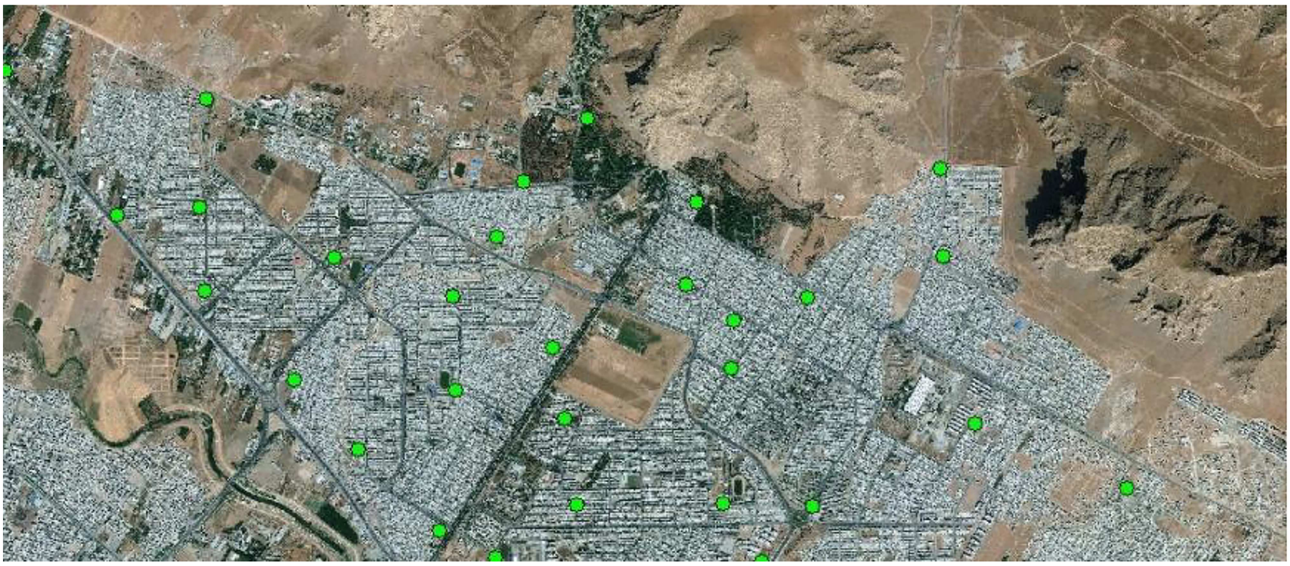

Figure 6. Determination of the proposed GIS coordinates to apply to the GA.

Figure 7. Location of BTS antennas in the north of Kermanshah at present.

based on the proposed map, there is a difference between the current antenna locations and the proposed ones in terms of number and location. The number of antennas decreased from 32 to 30 antennas and their installation location changed, as well (Figure 7).

Because the development process in privately owned urban areas, in addition to the high cost of providing and installing antennas, involves legal considerations and administrative procedures, an effective proposal to reduce operating time and costs is to relocate existing antennas to new locations in accordance with the project schedule and based on the progress of relevant legal actions.

4.7. The coordinates of the proposed GIS points

To optimize the proposed antennas obtained from GIS, we should consider the coordinates of these points in metric units. Then, we can apply these coordinates as the location of the antenna in MATLAB software and use GA to optimize them, as shown in Table 10.

4.8. Selecting important parameters to apply to the GA

The optimization problem is considered intractable for exact solutions using conventional methods, and finding the optimal solution may not be possible within

Table 10. Metric coordinates of proposed points.

No.	ID	X	Y	No.	ID	X	Y
1	KW1	5,240,519.15	4,081,944.01	16	SR16	5,247,710.45	4,077,103.85
2	RW2	5,241,583.33	4,080,498.56	17	SB17	5,244,593.92	4,077,418.97
3	SW3	5,242,342.68	4,080,591.17	18	NB18	5,245,705.02	4,079,192.63
4	SW4	5,243,660.31	4,080,072.58	19	NK19	5,246,036.94	4,081,447.28
5	RW5	5,242,416.77	4,079,749.79	20	NK20	5,245,431.75	4,080,824.28
6	RM6	5,243,258.14	4,078,876.00	21	NV21	5,245,208.55	4,080,274.92
7	KE7	5,249,702.11	4,078,502.83	22	MS22	5,244,799.85	4,078,777.89
8	NK8	5,249,425.27	4,080,094.57	23	NV23	5,247,424.17	4,079,452.12
9	NK9	5,249,397.49	4,080,953.67	24	NP24	5,247,062.90	4,080,636.63
10	MS10	5,248,190.45	4,077,636.32	25	NS25	5,242,396.60	4,081,677.71
11	MP11	5,247,328.44	4,077,693.47	26	SV26	5,244,769.41	4,079,702.89
12	MN12	5,247,398.82	4,079,011.36	27	MJ27	5,243,865.72	4,078,200.67
13	NJ13	5,246,991.62	4,079,807.89	28	EV28	5,248,126.82	4,079,687.03
14	MB14	5,245,807.96	4,078,511.25	29	SE29	4,077,868.01	5,251,185.02
15	SR15	5,245,184.08	4,077,129.39	30	NE30	4,077,563.50	5,245,964.59

a reasonable amount of time. To tackle this issue, we utilized a GA-based approach that is capable of handling real-life problems. GA is a bio-inspired, probabilistic search method based on the natural selection method, originally developed by Holland. Gen et al. demonstrated that GA would be an effective approach for obtaining near-global solutions [20].

GA is a powerful optimization technique that is based on the principles of evolution and genetics. It has proven to be effective in solving a wide range of optimization problems, including the challenging BTS placement problem. The process of designing a GA typically begins with solution encoding, creation of individuals that make a population, and evaluation of these individuals. During the evaluation, each individual is assigned a fitness value according to a certain fitness function. Based on the fitness value, a number of better individuals are selected to seed the next generation through crossover and mutation. In GA, variables can be represented in binary, integer, and real [21].

Based on the Pareto principle, out of 15 identified sub-criteria affecting location, only 5 sub-criteria, namely quality, sensitive points, imposed costs, quality of service, and coverage, are found significant in terms of their impact, while the rest of the sub-criteria can be ignored (Figure 8).

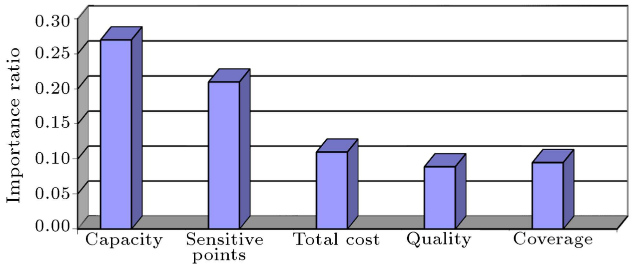

Figure 8. Important parameters.

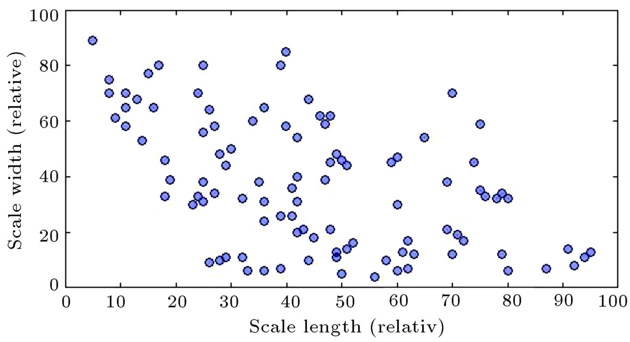

Figure 9. Accidental dispersion of users.

4.9. Location of applicants for contacting

To initiate the simulation, we randomly scattered 100 users in the target area who desire to make calls with the BTS antennas. The process of choosing these users was arbitrary and there was no limit to the number of users or their location. This study considered 100 users due to the quality of output images and their resolution. The random coordinates generated in simulator software are shown in Figure 9.

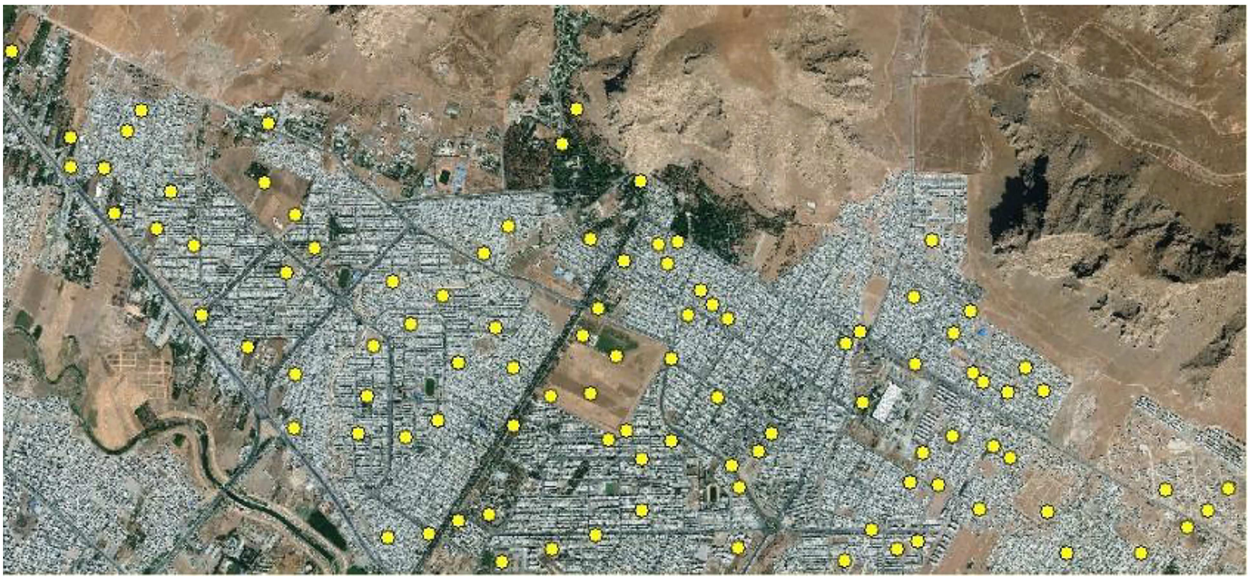

Figure 10. Random dispersion of users.

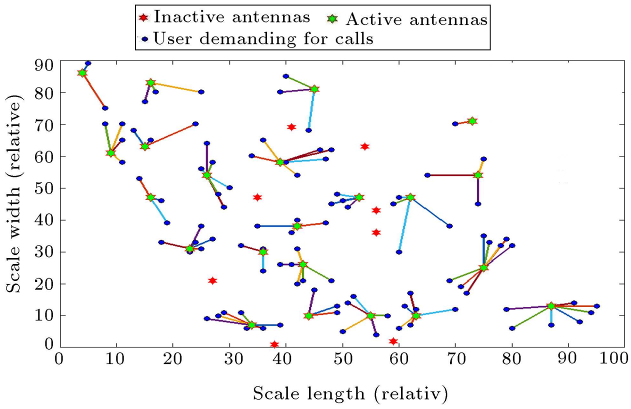

Figure 11. The number of active antennas using random selection.

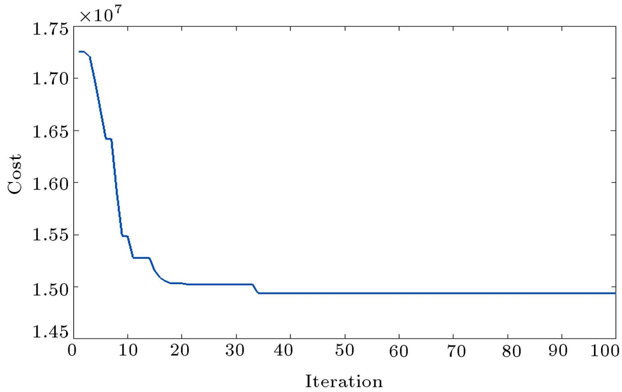

Figure 12. Reduced final cost obtained from repetition of the algorithm in random selection.

The location of users on the map is determined through coordinates of the points at which the users made their call (Figure 10).

4.9.1. The examination of the number of BTS antennas and the cost of providing service, with random selection

Considering that there were 100 randomly dispersed users selected for making calls with an average of five calls exposed to 30 antennas (extracted from the GIS) installed at locations with the specified coordinates, the random algorithm is applied to select the initial population, the number of active antennas, and coverage being shown in Figure 11.

According to Figure 11, only 22 randomly selected primary populations are used; 22 antennas are active and 8 other antennas remain inactive. Obviously, this is the case if all 100 callers are contacted by the closest antenna. Therefore, cost reduction is expected, as shown in Figure 12.

According to the above, the service cost will be 1.75 multiplied by 10 and exponent 7 at the beginning of im-plementing the algorithm which involves providing communication services with 30 BTS antennas for 100 users (each of which made 5 calls). Additionally, at the end of the algorithm implementation, this value (after 100 repetitions) will be 1.49 multiplied by 10 and exponent 7. In addition, it is assumed that the algorithm is uniform after the repetition of 34; and the excessive repetition of this amount does not contribute to the improvement of the algorithm.

4.9.2. The examination of the number of BTS antennas and the cost of providing services based on the tournament method of population selection

Considering the same conditions that had been considered in the random population selection method, if we use the initial population selection method as a tournament, the number of active antennas and how to cover users is shown in Figure 13.

It should be noted that 8 antennas have been

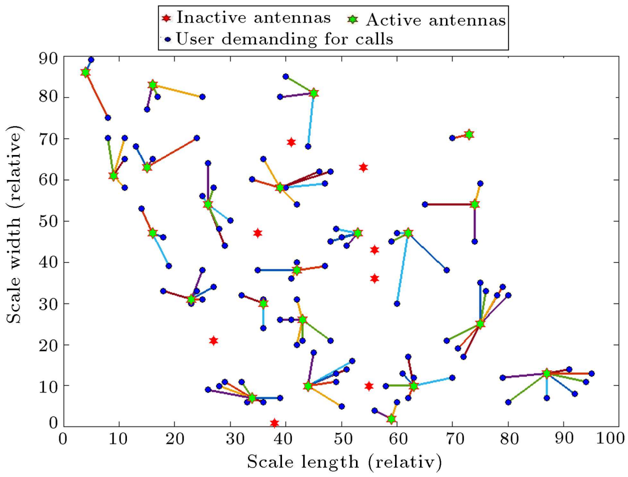

Figure 13. Number of active antennas via tournament selection.

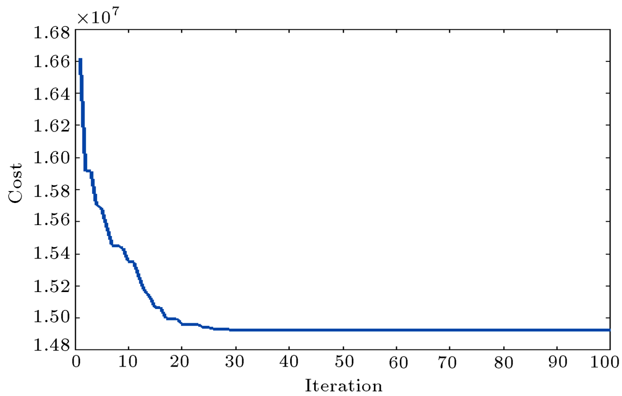

Figure 14. The amount of final cost reduced by the repetition of the algorithm through tournament selection.

inactive in this method. However, the location of inactive antennas has changed slightly (Figure 13).

The cost reduction chart in this method is given in Figure 14.

By using the selection method, it can be observed that the algorithm converges much faster and the final value is obtained at the 29th iteration. In addition, the service cost reduction in this method does not significantly differ from the random method.

4.9.3. The examination of the number of BTS antennas and the cost of providing service, with the rou-lette wheel selection method

Similar to the previous two methods, in case the roulette wheel method is adopted, the number of antennas and how to cover users is shown in Figure 15.

It should be noted that 8 antennas have been inactive in this method, hence no significant changes over the previous method. The reduction cost chart is depicted in Figure 16.

By using this population selection method, the algorithm reached the final value at iteration 28 and converged faster than the previous two methods. Also,

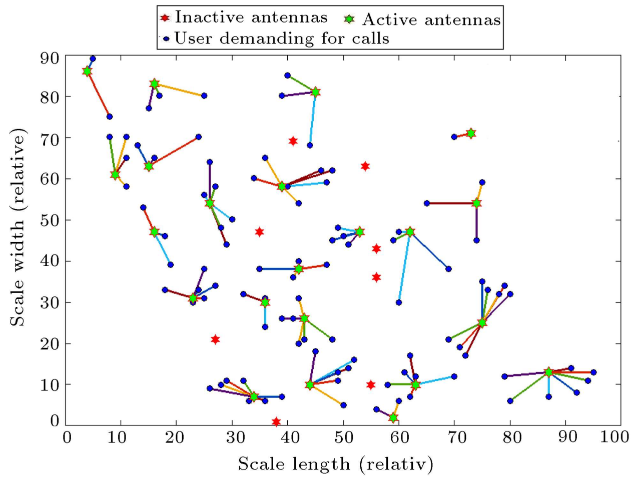

Figure 15. Number of active antennas using roulette wheel selection method.

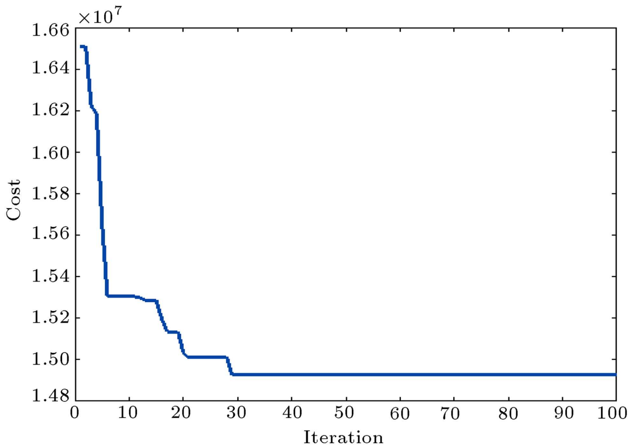

Figure 16. The amount of final cost reduced through the repetition of the algorithm through roulette wheel selection method.

the amount of cost reduction by using this method was found to be greater than that using the other two methods (1.485 multiplied by 10 to the power of 7).

The results of the final output of the genetic algorithm obtained using the 28 repetition convergence roulette wheel pattern are shown on the geographical map of the region. Yellow dots (location of existing antennas), red dots (active antenna) and green dots (inactive antenna) are displayed (Figure 17).

5. Conclusions

The results of alternate implementation of the algorithm indicates that integrating the innovative GA-based method deployed on the points with traditional methods such as Geographic Information System (GIS) led to the faster convergence of results, effective decrease in the number of antennas, and significant reduction of the service costs. This reduction in the total number of antennas and service costs resulted

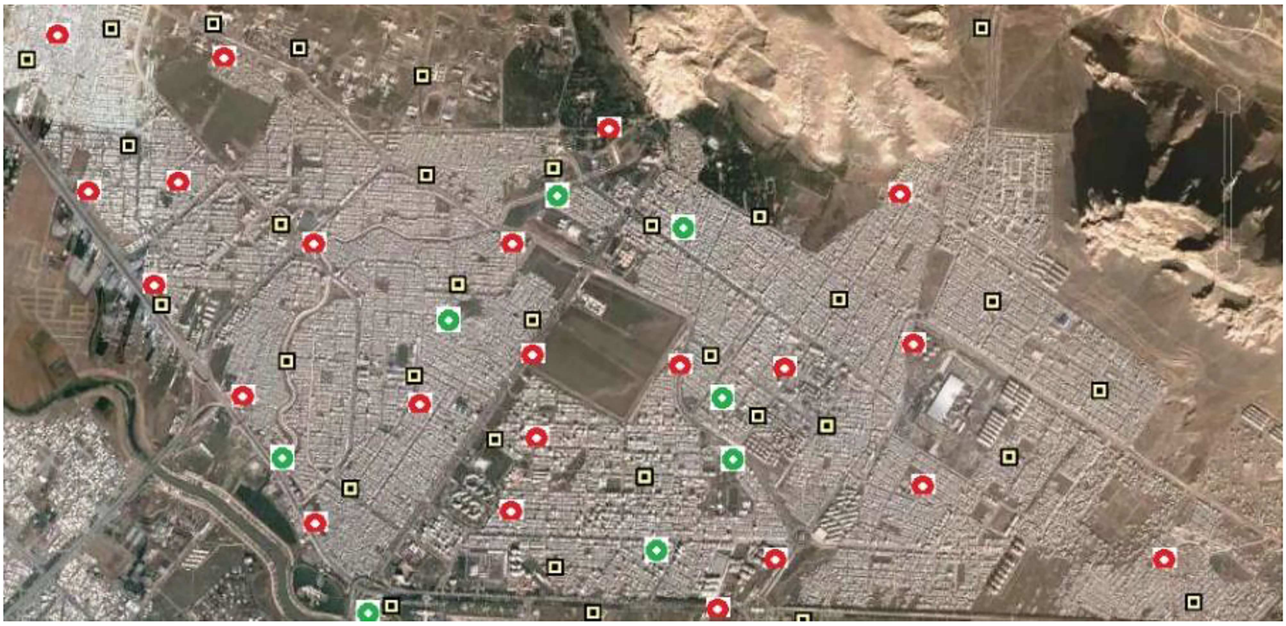

Figure 17. The best location of antennas according to the optimal output of the GA.

from intelligent determination of active and inactive antennas at any given time.

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Biography

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