Research Article

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An intelligent algorithm to reduce and eliminate coverage holes in the mobile network

https://doi.org/10.1515/jisys-2021-0046
received March 27, 2021; accepted May 28, 2021

Abstract: The need for services in the world of telecommunications and the prosperity and rapid development of this sector around the world has led mobile phone companies to compete to provide the best services to customers. One of these devices used for communications is the mobile phone. The mobile phone is simply an electronic device that is mainly serving unwired telecommunications through a cellular network of particular base stations known as cell sites. There are many obstacles or problems in the telecommunication field, and the relevant institutions and companies should find solutions to these obstacles and problems. One of these obstacles in telecommunications is the coverage holes. Coverage holes occur when the location of the mobile phone is set in midway between the two base transceiver stations (BTSs). This causes an abnormal interruption in communication until the user crosses the coverage holes area. This paper presents an intelligent algorithm as a set of technical steps that can be used to improve the communication services of the mobile phone network and to solve the communication problems via the reduction of the coverage holes between two BTSs. It suggests a method that could alleviate this problem using a strategy that reduces the coverage holes by developing an intelligent algorithm system to receive signal strength indicators and use AT command "+CREG" to disconnect and reconnect to available BTS within an acceptable energy level. As a result, the connection turned from marginal into good connection.

Keywords: internet of things, intelligent communications system, information technology, coverage holes, received signal strength indicator, base transceiver station

1 Introduction

Cells connecting depend on multivariable meaning that base transceiver station (BTS) do not always connect to the strongest signal to the mobile phone. Therefore, the estimation of the mobile may overlap with each other as the coverage holes, which causes abnormal interruption in communication [1,13].

Each reign will be divided into small areas with one (or more) BTS, which are used to cover the cellular system within these areas. This is done to increase the capacity of the connection, to reduce the power used for cellar system covering, and to minimize interference noise from other signals [2].

However, sometimes, different BTSs may not succeed to accomplish phone calls successfully. This is due to the fact that BTS has a limited coverage area that may be given to the mobile phone. When the phone

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exceeds this coverage area, it reaches what we call "coverage hole," which leads to stopping making calls until it discovers another tower that has a stronger signal that enables the mobile phone to receive a signal for continuing working to connection [3].

The present system is working automatically by ordering the mobile phone and the cell station to send the order to the BTS to increase the strong signal, which requires an increase in the power of the BTS, to transfer the mobile phone into a new frequency. Which is a costly process for telecommunication companies due to the increase of capacity, as well as the regular maintenance, furthermore that solution is ineffective while the problems are still existing [1,4,12].

Therefore, the proposed algorithm focuses on reducing the coverage holes time by developing an intelligent algorithm that establishes reconnection to the available BTS within acceptable energy level depending on the received signal strength indicator (RSSI) [4].

The developed algorithm uses the mobile phone database from home location register (HLR) in the telecommunication system. HLR contains a central database of all information of a subscriber who belongs to the number of subscribers and the organization of the network area in the long term. The data are sent from HLR in periodic time to specify the location of the mobile phone and to provide the probable results of the direction of the mobility of the mobile phone [5]. The visited location register (VLR) is a local database that contains a subset of subscriber information required for a call setup in a remote radio cell. The update of the VLR is accomplished by the roaming mobile station and the HLR [6].

When the mobile phone moves within the communication area, the signal will decrease as the mobile phone moves away from the supplier tower (BTS1). In addition, the signal energy of the (BTS) will increase outside the available range until it reaches the area (10–31) or 99, and in this area, the mobile phone is unable to work normally, and this is shown in Figures 1 and 5. Then, the proposed intelligent algorithm is activated, which disconnects the signal from the (BTS1) by using AT command "+CREG" and increasing the RSSI value to reconnection with the mobile phone to connect with (BTS2) so that the connection continues normally, as shown in Figure 6.

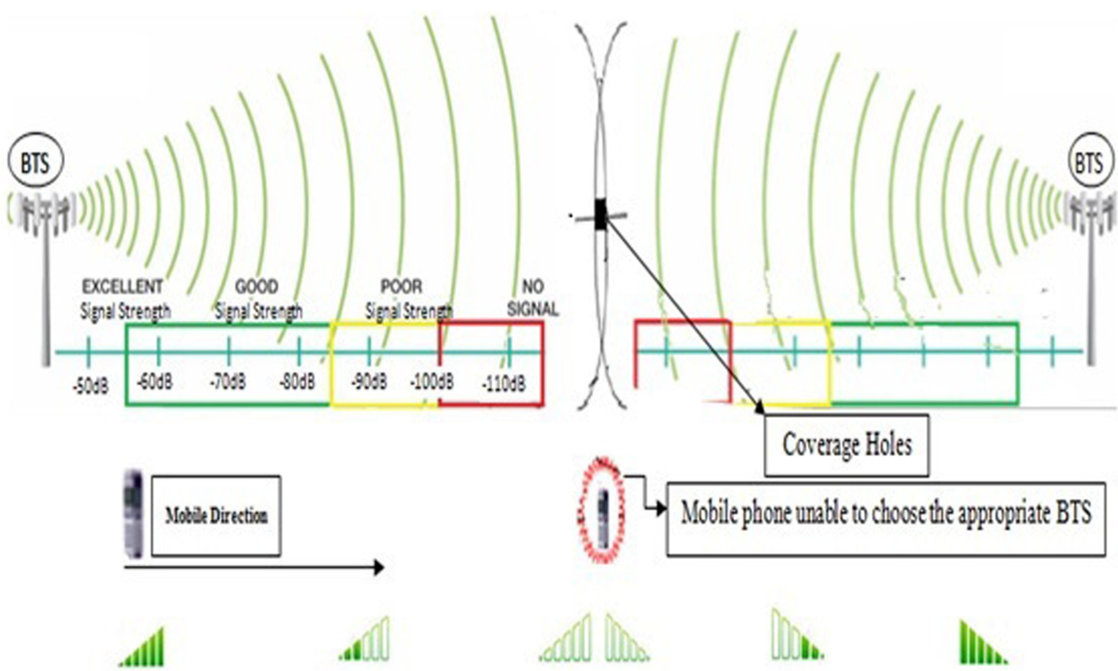

Figure 1: Problem statement and motivation.

The main contribution of this study is twofolds. In the first fold, this study develops an algorithm to minimize the coverage holes zone by using possible data processes from HLR and BTS map. In the second fold, the proposed algorithm will reduce the coverage hole by reconnecting to the available BTS within acceptable energy. This technique is used in telecommunication companies for mobile phones. This article is presented as follows: In Section 1, the introduction of the theories and principles is presented. In Section 2, the statement of problem and motivation for research are presented. In Section 3, the literature review of similar works by researchers who have published in the same field is presented. In Section 4, the proposed method is presented. In Section 5, the results and discussion are presented. In Section 6, the conclusion is presented.

2 Statement of problem and motivation for research

The problem statement and motivation shown in Figure 1 are explained.

There are many problems in telecommunication; the researchers are working hard to solve these problems. One of these problems is the coverage hole, which is a spot in the middle of two BTS where the mobile phone is unable to choose the appropriate BTS.

The mobile phone as mentioned earlier always receives the signal from the nearest BTS, which means that the nearest BTS is controlling all the mobile phone's activities. The BTS loses control over the mobile phone when it is out of the coverage area of the concerned BTS as well as when the mobile phone reached the coverage hole, so the conflict between two BTSs will start because both BTSs have the same characteristics to control, such as distance and the power of a signal, but in fact, the mobile phone is not working properly or there was an echo where using the mobile phone or the sound quality is bad.

The proposed solution by the researchers to solve the aforementioned problem is to build new BTS close to the coverage area, which costs a lot of money to telecommunication companies and another solution is to increase the coverage area to all BTSs, which have coverage hole that cost the company to increase the power of the electric generator and change the antenna to send a wider signal.

This article suggests that when the mobile phone's direction from BTS (A) toward the BTS (B) within the sectors and the mobile phone was under the control of BTS (A), the mobile will send a signal about its position to VLR and then to HLR. Before reaching the coverage hole, the control will change to BTS (B) while the mobile phone is moving from BTS (A) toward BTS (B) even if it does not reach the control zoon of BTS (B), and in the case the mobile phone reaches the coverage hole and then return toward BTS (A) zoon, the control will return to BTS (A). In this way, the cost of establishing new BTSs will be reduced, and the strengthening of old BTSs or increasing the coverage zoon as well as increasing electric power and upraise the maintenance will be negligible.

In other words, the increase of energy level emitting from BTS depends on the level of RSSI. This happens during calling the mobile phone when it continuously moves from place to place, "coverage holes," which affects mobile call communication.

3 Literature preview

The aim of this study is to develop an algorithm to minimize the coverage hole zone by using possible data process from HLR and BTS map. Furthermore, the proposed algorithm will reduce the coverage hole by reconnecting to the available BTS within acceptable energy. This technique is used in telecommunication companies for mobile phones.

A novel method for the redeployment of mobile nodes in a hybrid sensor network was proposed by Wu et al. [7]. The authors used the analytical hierarchy process for the optimal decision of a sensor node moving direction.

Enhancing the network coverage by using the locomotion ability of mobile nodes was proposed by Chellappan et al. [8]. The researchers studied the issue of mobility-based sensor network deployment and the sensitivity of performance to flip distance under different initial deployment scenarios. They determine a movement plan for the sensors to maximize the sensor network coverage and minimize the number of flips.

The parameters that affect the mobile communication performance and the coverage range were proposed by Sharma and Singh [9]. The authors measure the effect of the parameters on the signal power level in the up/down link and put into consideration the factors causing fading and other losses, the signal power.

Two polynomial algorithms for network segmentation and coverage-hole detection were proposed by An et al. [10]. The author has demonstrated the performance of the proposed algorithms. The results showed that the proposed algorithms are effective in detecting coverage holes.

The proposed algorithm named CHD-CR attempts to restore coverage after a coverage gap is detected, which was proposed by Amgoth and Jana [11]. The researchers used the algorithm consisted of the hole detection (CHD) and restoration (CR) stages. The simulation results showed that the proposed CHD-CR algorithm is superior to the existing algorithms in terms of maintaining coverage for a longer period.

A method of assessment of long-term evolution (LTE) coverage holes was proposed by Gómez-Andrades et al. [12]. The researchers determined the location, type, and severity of coverage holes, as well as identified and analyzed the impact of each coverage gap on users in both LTE and the basic radio access technology at the same time.

Most of the previous studies attempt to find direct solutions to this problem; however, when looking at the surrounding environment for this problem, there are many variable tools that must be taken into account, which could give better results if it were used. For example, well-distributed communication towers cover the growing growth of subscribers.

4 The proposed method

In this article, the technique used to collect the effective data and knowledge is based on BTS, VLR, HLR, and RSSI and all periodically sent information for mobile phones including the distention. Therefore, the dataset used in this article consists of RSSI, arbitrary strength unit (ASU), BTS, (AT) commend "+CENG," HLR, which contained VLR and mobile switching center (MSC).

The outputs are arranged by providing the guideline of HLR to deal with automatic data processing as well as BTS map on the selected combinations of many BTS. The BTS depends on RSSI, which has values representing the received power from the service cell, co-channel power, and other noise sources (Table 1). By using a developed algorithm, possible data processed from HLR and BTS map are made to minimize the coverage holes zone as shown in Figures 2 and 3.

MSC that controls the chosen BTS to give the priority to proactive BTS to mobile phone to be under its control is shown.

The proposed method to reduce coverage holes algorithm is shown in Figure 4. It is summarized here.

Normally, a mobile phone receives a signal from the nearby BTS. The mobile phone signal decreases when the mobile phone moves away from BTS. Until it is impossible to make a telephone call or do not work well because the mobile phone signals in this area do not exist (coverage holes).

The mobile phone moves from one area to another to receive the signal from another BTS. The structure of the algorithm for reduction the coverage holes is based on the following steps.

- As the first step, the RSSI value that received a signal of the mobile phone is determined. The strength of the mobile phone signal is measured by RSSI, to determine whether the call could be achieved, (Table 1).
- Then, the current registered for BTS and the other available BTSs of the network operator is determined. The direction of the mobile is determined. In addition, the second expected location of the BTS is determined. This is done through the continuous movement of the phone transmission. The location of the mobile phone is determined between the ranges of the signal of the tower and the signal strength of the mobile phone (Figures 2 and 3).
- From the other side, MSC will determine the expected BTS depending on the movement of the mobile phone and the strength of the signal when the mobile phone reaches the point as shown in Figure 5.

Table 1: Values of RSSI before applying the proposed algorithm

Value	RSSI (dBm)	Condition
0	−113	Marginal
1	−111	Marginal
2	−109	Marginal
3	−107	Marginal
4	−105	Marginal
5	−103	Marginal
6	−101	Marginal
7	−99	Marginal
8	−97	Marginal
9	−95	Marginal
10	−93	Ok
11	−91	Ok
12	−89	Ok
13	−87	Ok
14	−85	Ok
15	−83	Good
16	−81	Good
17	−79	Good
18	−77	Good
19	−75	Good
20	−73	Excellent
21	−71	Excellent
22	−69	Excellent
23	−67	Excellent
24	−65	Excellent
25	−63	Excellent
26	−61	Excellent
27	−59	Excellent
28	−57	Excellent
29	−55	Excellent
30	−53	Excellent
31	−51	Excellent
99	−49	No signal

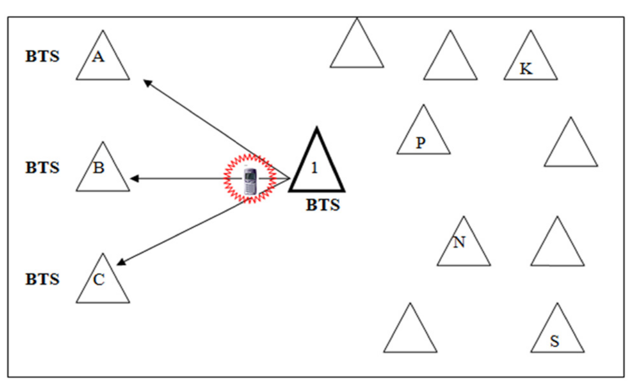

Figure 2: BTSs map.

- Collecting the information from the previous steps will determine the distance between the mobile phone and the coverage holes as well as the identification of both BTSs that the mobile phone located between them.

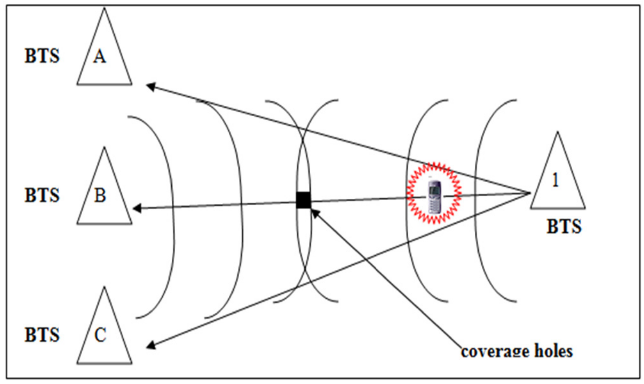

Figure 3: Illustration of the case study.

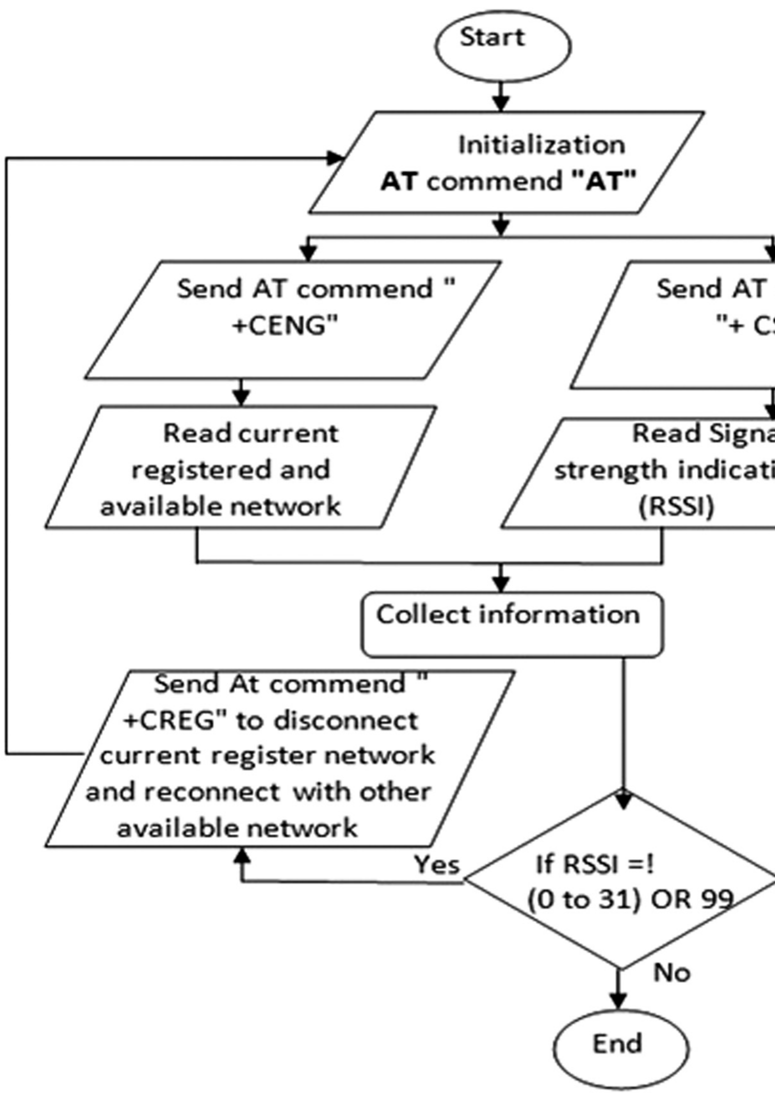

Figure 4: Reduction coverage holes algorithm.

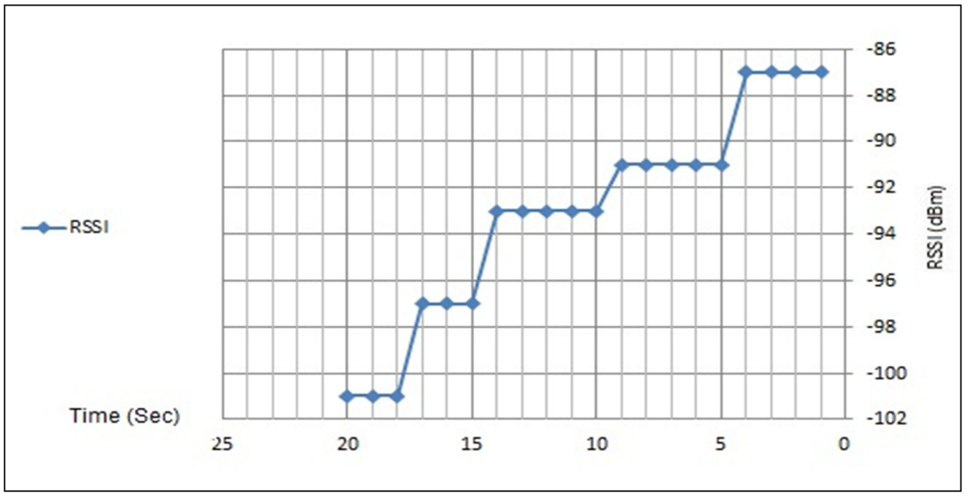

Figure 5: RSSI values in status connection inter coverage area.

- When the mobile phone reaches the coverage holes area, the algorithm will increase the mobile phone signal by RSSI and then sent the instruction to MSC to change the BTS tower control as shown in Figure 6.

5 Results and discussion

The outputs are arranged to provide the guideline of HLR to deal with automatic data processing and BTS map to select combinations of many BTS. To identify and distribute BTS constellations on the ground, and despite this distribution, many coverage holes will appear. Tackling these coverage holes cost telecommunication companies a lot of money in addition to the need for a greater technical staff to construct and maintain them. BTS depends on the RSSI, which has values representing the received power from the service cell, co-channel power, and other noise sources as shown in Table 1 and Figure 5. More precisely, the decreasing of energy level emitting from BST depends on the level of the RSSI as shown in the results of the mobile network BTS (Table 1). This will happen during calling the mobile phone continuously moving from place to place, "coverage holes," which affect mobile call communication as shown in Figure 5.

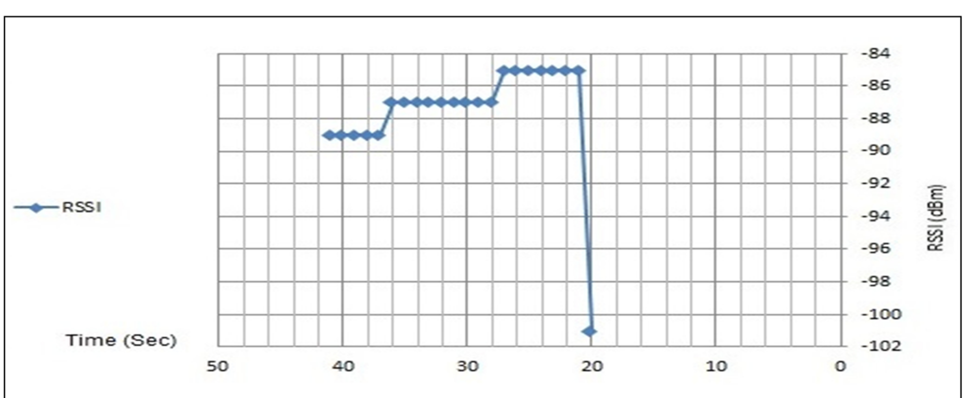

Figure 6: RSSI value when reconnection with network BTS.

Then, the intelligent algorithm will reduce a lot of money and time for the communication companies to make the connection happen naturally as well as change the connection status from unacceptable connection to acceptable connection as shown in Table 2 and Figure 6.

Table 2: Results of mobile network BTS information after applying the algorithm

No.	RSSI (dBm)	ASU	Signal evaluation	arfcn	MCC	MNC	LAC (hex)	BTS_ID
1	−87	13	Ok	0084	418	05	1023	31
2	−87	13	Ok	0084	418	05	1023	31
3	−87	13	Ok	0084	418	05	1023	31
4	−87	13	Ok	0084	418	05	1023	31
5	−91	11	Ok	0084	418	05	1023	31
6	−91	11	Ok	0084	418	05	1023	31
7	−91	11	Ok	0084	418	05	1023	31
8	−91	11	Ok	0084	418	05	1023	31
9	−91	11	Ok	0084	418	05	1023	31
10	−93	10	Ok	0084	418	05	1023	31
11	−93	10	Ok	0084	418	05	1023	31
12	−93	10	Ok	0084	418	05	1023	31
13	−93	10	Ok	0084	418	05	1023	31
14	−93	10	Ok	0084	418	05	1023	31
15	−97	8	Marginal	0084	418	05	1023	31
16	−97	8	Marginal	0084	418	05	1023	31
17	−97	8	Marginal	0084	418	05	1023	31
18	−101	6	Marginal	0084	418	05	1023	31
19	−101	6	Marginal	0084	418	05	1023	31
20	−101	6	Marginal	0084	418	05	1023	31
21	−85	14	Ok	0723	418	05	1023	01
22	−85	14	Ok	0723	418	05	1023	01
23	−85	14	Ok	0723	418	05	1023	01
24	−85	14	Ok	0723	418	05	1023	01
25	−85	14	Ok	0723	418	05	1023	01
26	−85	14	Ok	0723	418	05	1023	01
27	−85	14	Ok	0723	418	05	1023	01
28	−87	13	Ok	0723	418	05	1023	01
29	−87	13	Ok	0723	418	05	1023	01
30	−87	13	Ok	0723	418	05	1023	01
31	−87	13	Ok	0723	418	05	1023	01
32	−87	13	Ok	0723	418	05	1023	01
33	−87	13	Ok	0723	418	05	1023	01
34	−87	13	Ok	0723	418	05	1023	01
35	−87	13	Ok	0723	418	05	1023	01
36	−87	13	Ok	0723	418	05	1023	01
37	−89	12	Ok	0723	418	05	1023	01
38	−89	12	Ok	0723	418	05	1023	01
39	−89	12	Ok	0723	418	05	1023	01
40	−89	12	Ok	0723	418	05	1023	01
41	−89	12	Ok	0723	418	05	1023	01

In the coverage area, power will rise out of the available range of 10–31 or 99. An intelligent algorithm will count that and use AT command "+CREG" to disconnect with the current registered network and reconnection as shown in Figure 6.

Firstly the code will downloaded then the connection setup will made by using Arduino mobile shield to connect with one of the mobile phone operator network companies' as shown in Figures 7 and 8. "Mobile Network Cell Info Lite" and "GSM BST Info" applications were used to get network information to support the results of this study as shown in Figure 9.

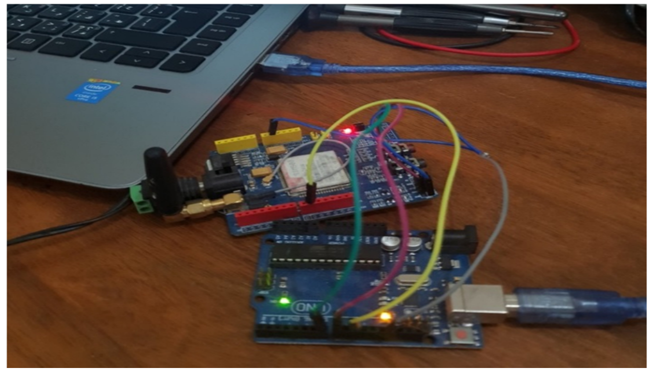

Figure 7: Mobile shield 900 with Arduino and UNO.

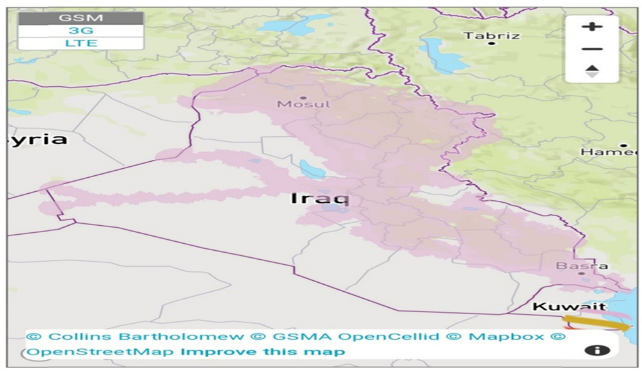

Figure 8: Map one of the mobile phone network operator in Iraq.

The response of AT commend “+CSQ” returns the signal strength of the registered cellular network and the value from 0 to 31 or 99. The AT commend “+CENG” return the following values: “number, Absolute Radio Frequency Channel Number (arfcn), rx_level, rx_quality, the mobile country code (MCC), mobile network code (MNC), base_station_identity_code (dec), CELL_ID (hex), receive_ level_ access_minimum, transmit_power_max, LAC (hex), timing _advance,” and the results of which are presented in Table 2.

As mentioned earlier, the achievements in the research are to reduce the coverage hole. Conversely, the signal strength has been affected in other areas although it is still working in an acceptable way. Nevertheless, there are sites where coverage hole still exists, but only marginally, and AUS ranges between 6 and 8. In more details, the decreasing of energy level emitting from BTS depends on the level of RSSI. RSSI is a measurement of how well the device receives a good signal. This happens during the mobile phone calling with continuous moving from place to place, “coverage holes,” which affects mobile call communication.

ASU is an integer value proportional to the received signal strength measured by the mobile phone.

Figure 10 shows the movement of the mobile phone down to the coverage slot and how it goes out of range, as well as how the proposed algorithm works to reconnect well.

6 Conclusion

This study presented an intelligent method to enhance communication using the global system for mobile communication (GSM) by reducing the coverage hole between the different BTSs, which lead to improve the performance of HLR. The intelligent algorithm is developed to minimize the coverage holes zone by using

Figure 9: Output mobile network cell info lite and GSM BTS Info applications.

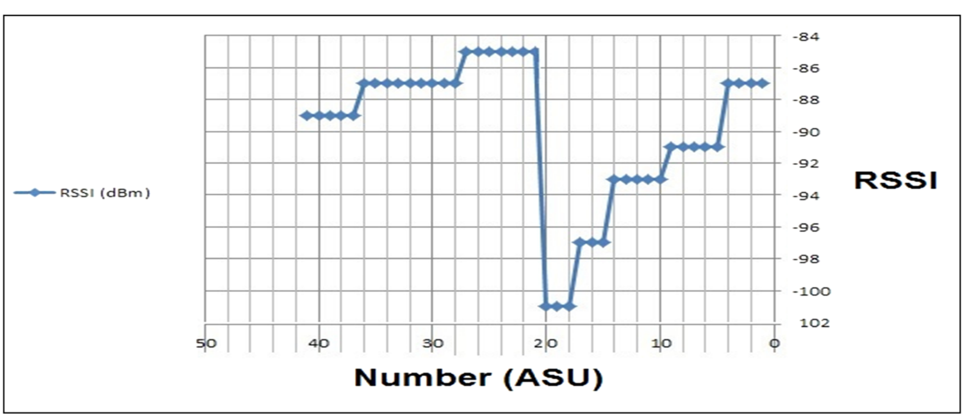

Figure 10: Current connection and reconnection with network BTS depend on the RSSI value.

possible data processing from HLR and BTS map by providing a reconnection to available BTS within to reduce the coverage hole by reconnecting to the available BTS within acceptable energy. This experiment showed that there is a big improvement in the signal between the different BTS stations.

The scope of this article included applying an algorithm that was developed to handling mobile phone malfunction's when it is located in a coverage holes region by determining the elected BTS and the expected destination for the mobile phone. We took into account the distribution of the BTSs in the area, but focused on two BTSs only. To move forward, we want to expand this research in the future by choosing three or more BTSs, at the time that one BTS works in a supportive manner to other BTSs, to reduce effort and obtain high efficiency when making a phone call.

This process is costing the companies a lot of money because of the increase in capacity, and in addition, it needs frequent regular maintenance and the solution is not satisfactory. As the problem still exists despite the improvement made by the smart algorithm, as shown in Table 2, we have not yet reached the solution to the coverage gap by 100%, and so we suggest to researchers to increase this signal evaluation.

Acknowledgment: Many thanks to Mustansiriyah University (www.uomustansiriyah.edu.iq), Faculty of Education and Computer Science Department/Baghdad-Iraq for supporting us in this work.

Conflict of interest: Authors state no conflict of interest.

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