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Experimental Evaluation of the Local Packing Distributed Dynamic Channel Allocation Strategy Application for AI-Madar Telephone Telecommunication Network in Libya

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ABSTRACT

The great challenge of the remarkably growing demand for personal communication mobile service in Libya has actively motivated Al-Madar Telephone Telecommunication Company to adopt various techniques in order to substantially improve its network capacity. An efficient allocation strategy of communication channels that could ensure good performance of the cellular network is critically needed, given the limited spectrum currently available that uses the Fixed Channel Allocation (FCA) strategy. In this study, experimental investigations were conducted to improve Al-Madar Company network by proposing the evaluation of the adoption of the Local Packing Distributed Dynamic Channel Allocation (LP-DDCA) strategy. The main reasons for proposing the adoption of the LP-DDCA strategy are; to minimize the call blocking probability, enhancing the network performance and increasing the number of network subscribers. This work has been done by applying actual data from an existing cellular network of Al-Madar Company in to the experimental simulation program. The results demonstrated clearly the superiority of the proposed the LP-DDCA strategy in the investigated locations (cells) compared with the currently used FCA strategy. Conclusion: Application of the LP-DDCA strategy could give rise to substantial improvement in Al-Madar telecommunication mobile network performance and it will considerably increase the number of network subscribers.

Keywords; The Local Packing Distributed Dynamic Channel Allocation strategy, Call blocking probability, Al-Madar Company, Mobile Cellular Communication, Mobile Telecommunication Network capacity.

I. INTRODUCTION

Personal cellular telecommunication all over the globe is growing rapidly and in parallel to that; the communication technology is progressing vastly. Furthermore, the Global Personal Communication networks are under extensive active academic research trying to find evidence based solutions to the current and prospective challenges [1].

Different schemes for channel allocation have been proposed in the literature in last three decades [2] [3] [4]. These Channel allocation schemes can be divided in to a number of different categories depending on the comparison basis. When the channel assignment algorithms are compared based on the manner in which co-channels are separated, they can be divided into; Fixed Channel Allocation (FCA), Dynamic channel allocation (DCA) and Hybrid channel allocation (HCA).

The simplest categorical scheme is a fixed channel allocation (FCA). The main advantage of FCA scheme is its simplicity; however it is not adaptive to changing traffic conditions.

The Libyan AI-Madar Telephone Telecommunication Company was established in 1996 and launched in 1997. Its existing cellular network is designed to serve 300,000 subscribers [5] with target penetration of 5% and it is continuously adopting research proved strategies to achieve its planned targets and increasing the targeted penetration percentage to be more than 5%.

It is currently using FCA scheme, however, the existing cellular frequency band is strictly divided among cells and the efficiency of the existing spectrum is restricted due to short term temporal and spatial variations of traffic in cellular system, FCA schemes are not able to attain high channel efficiency.

The following are three techniques that the Al-Madar company has adapted so far to enhance its network capacity and to maintain their grade of service (GOS):

[A] Cell Splitting.
[B] Half Rate Traffic Channel.
[C] Load Sharing.

[A] Cell Splitting

The creation of smaller geographical cells can result in better use of the existing spectrum allocation via higher degree of spatial reuse. There is a minimum cell radius; however, in some areas this limit has already been reached [6].

[B] Half Rate Traffic Channel

The traffic channels carrying Speech and data Information are of two types; The Full rate traffic Channels (FTCH) and the Half Rate Traffic Channel (HTCH).

The traffic channels are two-way channels using the normal burst format (which is shown in Fig.1 in a multiframe consisting of 26 Time Division Multiple Access (TDMA) frames with 8 time slots per carrier. Fig.1shows the length of the burst is slightly shorter than the duration of the time slots. This is to allow for the burst alignment errors, time dispersion on the propagation path, and the time required for smooth switch (on//off) of the transmission.

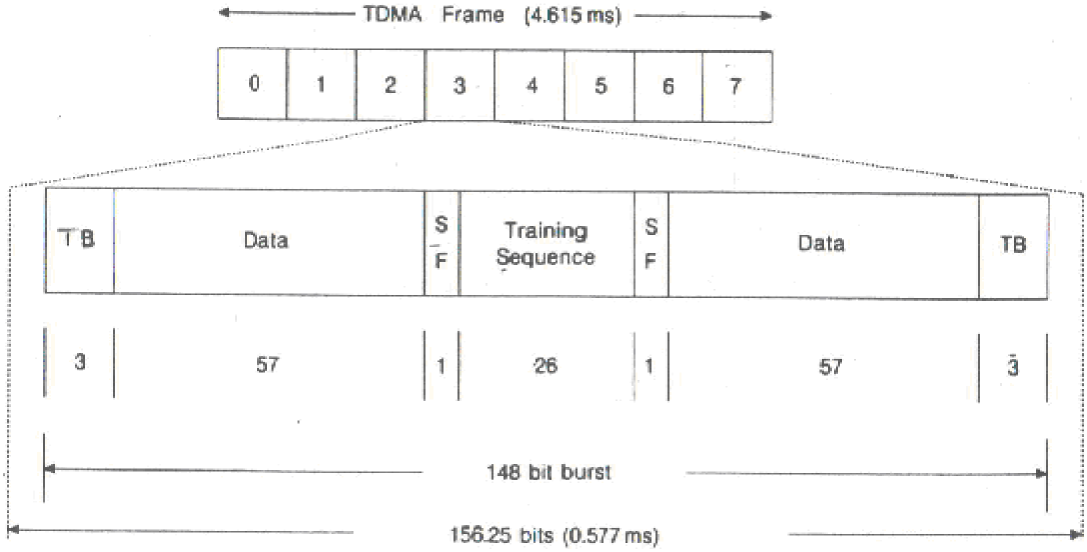

Figure.1: Normal burst in Global System for Mobile communication (GSM). TDMA (Time Division Multiple Access), TB=Tail Bits, SF=Stealing Flag.

Fig.1 shows also the data structure within a normal burst which includes the following:

- **114 (2X57)** bits that are available for data transmission and the remaining bits are used to assist reception and detection**.**
- **A training sequence** (26 bits) in the middle of the burst is used by the receiver to synchronize and estimate the propagation characteristics.
- **Tail bits** (TB) (3 bits) transmitted at either end of the burst enable the data bits near the edges of each burst to be equalized as well as those in the middle.
- **Two Stealing Flags** (SF) [one bit at each end of the training sequence]are used to indicate that a burst which had initially been assigned to a traffic channel has been stolen for signalling purposes
- **The FTCH** uses 24 frames out of 26 in the multiframe. One of the 26 frames is used for Slow Associated Control Channel (SACCH) and one remains idle.
- **The duration of the multiframe** is therefore 26 (Number of frames) X 4.615 ms (The duration of each frame) =120 ms. Therefore, FTCH is 24 (The Number of normal bursts per 120ms multiframe) X 114(Data bits per normal burst)/0.125(the duration of the multiframe) = 22.8Kilobits/Second.

In the case of HTCH, each traffic channel occupies only 12 frames which results in a HTCH bit rate of 11.4 Kilobits/Second for each **[7]**

Al-Madar Company uses FTCH unless there is congestion in some cells, so it changes towards HTCH to cover the large demand by decreasing the quality of voice to offer more traffic channel.

[C] Load Sharing:

This specific technique is used when there is a call request in a particular cell and there is no free channel to serve that request. In such a case; the base station of that cell tries to make a forced handover to that call to one of its neighboring cells by using special algorithm to measure the Carrier to Interference Ratio (CIR) of each neighbor cell and request information about the available number of free channel in each neighbor cell, according to this information the base station decide to which cell the requested call should be forced to handover.

Carrier to Interference Ratio (CIR) is a measure of signalling effectiveness. It is expressed in decibels. The carrier is the desired signal and the interference detracts from the quality of the received signal. Interference can refer to interference from other carriers or it can refer to background noise.

This study proposes the use of alternative strategy called dynamic channel allocation (DCA) in which channels are dynamically assigned to the used cells, in order to overcome the limitations of the FCA scheme [8] [9].

In DCA scheme, all channels are kept in a central pool and are assigned dynamically to radio cells as new calls arrive in the system as needed such that the minimum carrier-to -interference ratio (CIR_{min}) criterion is satisfied. After a call is completed, its channel is returned to the central pool.

In order to evaluate the performance of DCA, two schemes can be used in two different fashions; Centralized DCA (CDCA) and Distributed DCA (DDCA).

This study has conducted the experimental investigations of the usage of the Local Packing Distributed Dynamic Channel Allocation (LP-DDCA) strategy as a new enhancement approach that could bring a significant as well as a viable economical and practical enhancement to Al-Madar current telecommunication network capacity and performance.

II. METHODOLOGY AND EXPERIMENTAL WORK DESCRIPTION

II.1 Simulation Procedure for implementing DCA strategy with AI-Madar network

1. Selection of the Area

To find the improvement that could occur to Al-Madar Company network when implementing LP-DDCA strategy, a region need to be selected as a first step. The selected region is located in Tripoli; its borders are; Abo Saleem region from the East, Gorgee region from the west, the coast from the north and Drabie from the south. This region has been selected because of its characteristics, as a busy area where micro cells are applied, that increase the difficulties of frequency planning, which implicate more challenges to have such a performance enhancement with FCA strategy.

2. Cellular Networks principles and Frequency re-use distance

I] <u>Cellular Networks principles:</u>

With the cellular concept, each area is divided in to hexagonal-shaped cells.

A cell is defined by its physical size and more importantly by the size of its population and traffic patterns. Each cell is allocated a band of frequencies and is served by base station which is a radiofrequency transceiver (consisting of transmitter, receiver, and control unit) located at approximately the physical center of each cell.

The function of the base station is to interface between mobile telephone sets and Mobile Telephone Switching Office (MTSO).

The physical size of a cell varies depending on the user density.

Microcells (like that of interest which is used by Al-Madar Company of the selected area in this study) are used most often in cities, where they can appear in the streets and inside the buildings [10].

Each cell is allocated a different carrier frequency and it has a usable band width associated with this carrier because only a finite part of the radio spectrum is allocated to cellular radio the number of the carrier frequencies available is limited.

This means that it is necessary to re-use the available frequencies many times in order to provide sufficient channels for the required demand.

With a fixed number of carrier frequencies available, the capacity of the system can be increased by re-using the carrier frequencies more often [7].

The cells which collectively use the complete set of the available channel frequencies are called a cluster [10]. The cells with the same number in Fig.2 use the same set of channel frequencies [10].

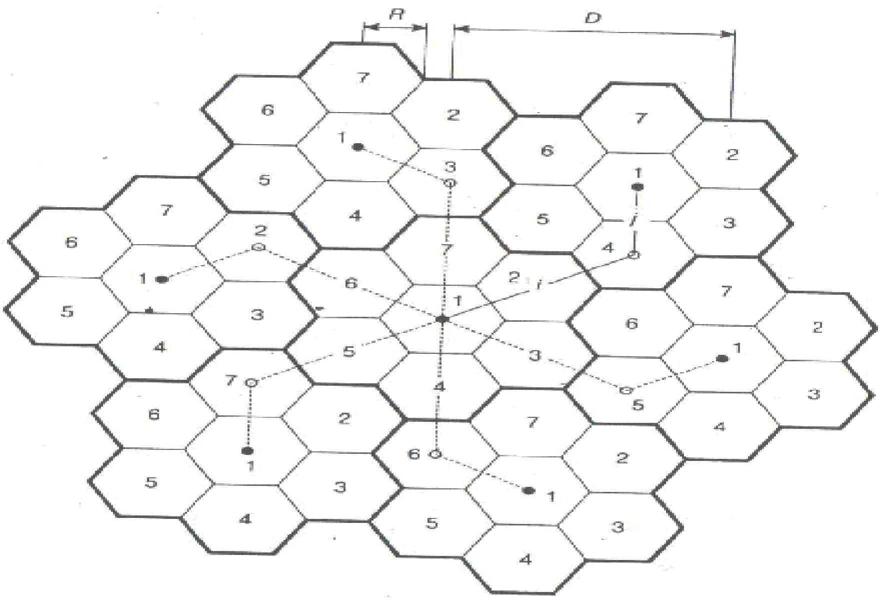

Figure.2: Cell cluster with K=7.

II] Frequency Re-use Distance:

The actual frequency re-use distance is D as shown in Fig.2 Considering the radius of a hexagon is defined to be the radius of the circle that circumscribes it (equivalently, the distance from the center to each vertex; also equal to the length of a side of hexagon) [11].

For a cell radius (R), *the frequency re-use distance may be determined by applying Equation I* [7].

$$D = R\sqrt{3K} \qquad \textbf{Equation I}$$

Where,

K is a number of cells per cluster (the cluster size).
The cluster size is specified in terms of offset of the centre of a cluster from the centre of adjacent cluster.

This can be made clearer by reference to Fig.2
The cluster size is calculated using Equation II [7].

$$\mathbf{K} = i^2 + ij + j^2 \qquad \textbf{Equation II}$$

Where **i** and **j** = non negative integer values.

Common cluster sizes are 4 (i=2, j=0) and 7(i=2,j=1) for city centres (like that of interest which is used by Al-Madar Company in the selected area in this study), and 12(i=2,j=2) for rural areas [7].

The objective is to use the same frequency in other nearby cells, thus allowing the frequency to be used for multiple simultaneous conversations.

Generally, 10 to 50 frequencies are assigned to each cell, depending on the traffic expected [11]. *However, in order to maximize frequency re use,* it is necessary to minimize the frequency re-use distance. Hence the design goal is to choose the smallest value of K which will meet the requirements in terms of capacity and interference [7].

3. Co-Channel interference:

With frequency re-use, several cells within a given coverage area use the same set of frequencies.
Two cells use the same set of frequencies are called Co-Channel cells and the interference between them is called Co-Channel interference. To reduce the Co-Channel interference, co-channels must be separated by a certain minimum distance [10]. For hexagonal geometry, the Co-Channel re-use-ratio can be measured by using Equation III and Equation IV [10].

$$Q = \frac{D}{R} \qquad \textbf{Equation III}$$

$$Q = \sqrt{3K} \qquad \textbf{Equation IV}$$

Where;

Q=*Co-channel re-use-ratio (unit less)*
D=*The actual frequency re-use distance (the distance to the centre of the nearest co-Channel cell) [Kilometres]*
R=*Cell Radius [Kilometres]*
K=*Cluster Size [Number of cells]*

In addition to constraining Co-Channel interference, the design of a wireless cellular system must also include measures to limit Adjacent Channel Interference (ACI).

Channel impairments such as crosstalk, premature handoffs, and dropped calls may result from ACI, leading to degradation of quality of service.

Although channel filters in both the base station and the mobile unit receivers significantly attenuate signal from adjacent channels, severe interference may occur in circumstances where the received signal level of an adjacent channel greatly exceeds that of the desired channel.

This situation arises often in mobile cellular environments due to the distance differences between the mobile units and the base stations. To reduce ACI, typical cellular systems employing FCA avoid the use of adjacent channels in the same base station.

In this experimental study, the channels impairments constraints such as Co-Channel Interference and Adjacent Channel Interference (ACI) which can result in multiple Channel impairments (crosstalk, premature handoffs, and dropped calls) were well dressed by excluding the edge cells from the experimental cellular performance evaluation algorthium.

4. Determine the number of cells

In the case of a cellular system using DCA algorithm, not only one sample cell should take in to account, but also neighbouring cells (six cells in the hexagonal model) of the selected region under interest, because co channel interference from neighbouring cells has a significant effect on the performance of the sample cell.

The boundary cell has different performance than the inner located cell, so consequently, taking user activity in the boundary cell as well as that in an inner cell into account does not adequately evaluate DCA performance.

Thus, to avoid such a problem, the solution which could be used is to take data only from inner cells and exclude boundary cells.

Therefore, 19 cells out of 37 cells which consist of the selected region under interest will be included in the performance evaluation, as the edge cells will be neglected, as shown in Fig.3.

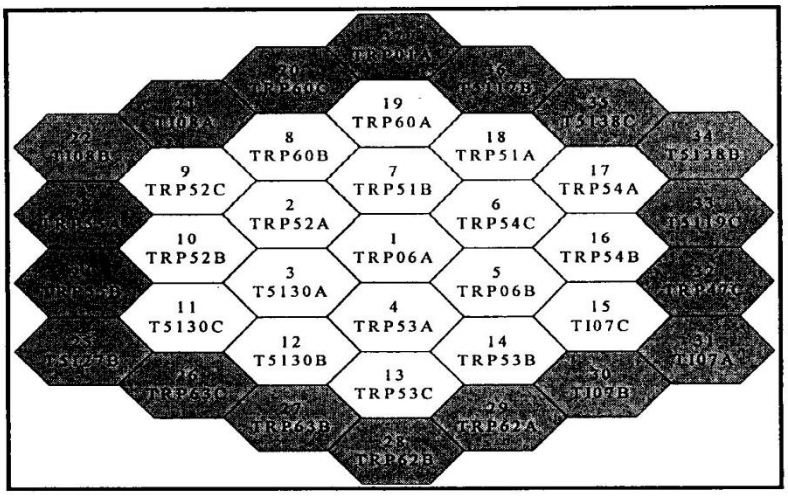

Figure.3: The selected cells model.

5. <u>**The calculations of the offered Traffic and the number of users at each cell:**</u>

A. The offered traffic has been calculated by actual measurement of carried traffic in each cell taken by Al-Madar Company (***Equation V Appendix I***).

B. Considering the average offered traffic per user 0.0458 Erlang , average holding time 55 sec and average arrival rate 3 call / hour as per Al-Madar Company data [5] and from step (A), the number of users per each cell can be calculated using ***Equation VI Appendix I***.

6. <u>**Determining the number of the traffic channels at each cell:**</u>

Broadcast Control Channel (BCCH) is the digital logical control channel that is used to carry generic system related information about the network, the cell in which the mobile is currently located and the adjacent cells. BCCH is a unidirectional base station to mobile unit transmission shared by all mobile units [7] [10].

The company has 64 carriers available to its network, 22 of these carriers are BCCH and each BCCH Carrier has 8 time slots, 4 time slots for signalling purposes and the other slots for traffic load, the rest are traffic carriers each one of these carriers has 8 time slots allowed to carry traffic load. From the frequency plane used by the Al-Madar Company, it is found that 62 carriers were allocated to the selected area, these carriers consists of 22 BCCH Carriers and 40 as Traffic carriers.

<u>***The number of total traffic channels at each cell can be calculated using the following equations;***</u>

<u>**Knowing the following data;**</u>

- *Number of BCCH carriers=22*
- *Time slots for each traffic channel=4*
- *Number of Traffic channel carriers=40*
- *Time slots of each Traffic channel carrier=8*

Time slots for all BCCH carriers traffic channels*= Number of BCCH carriers X Time slots for each traffic channel* → 22X4=***88*** (***Equation VII***)

Time slots for all traffic channels carriers*= Number of Traffic channel carriers X Time slots of each Traffic channel carrier-→40X8=**320*** (***Equation VIII***)

Total traffic channel carriers available for users at each cell *= Time slots for all BCCH carriers traffic channels+ Time slots for all traffic channels carriers-→ 88+320=**408*** (***Equation IX***)

This results in 408 traffic channels available to users in each cell.

Table I in appendix I shows the following data for each tested cell;

- *The number of traffic channel at each investigated cell*
- *Traffic per user (No.TRU)*
- *Traffic Channel (No TCH)*
- *Average number of users per Km^2*

7. The calculations of both; the cell radius and the resulted minimum actual Frequency re-use (Co-Channel) distance that satisfy the minimum CIR (CIR min =9dB):

The LP-DDCA strategy works to make the whole channels (carried frequencies) available to all cells of the network, and when a cell request a channel then the appropriate channel that satisfy the CIR min will be utilized by the cell. Therefore, it is necessary to determine the minimum actual frequency re-use (Co-Channel) distance that satisfy the given of the CIR min of each cell in the network of the selected region by Al-Madar Company as following;

The cell radius of each cell was calculated using ***Equation X appendix I.***

The resulted minimum actual Frequency re-use distance that satisfies *the CIR min of each cell* was determined using ***Equation XI appendix I.***

By knowing the coordinates of each tested cell [5] and its minimum actual Frequency re-use distance (D), each cell that falls within the re-use distance of a particular cell can be known.

8. System capacity:

The system capacity of a telecommunication network may be described in terms of the number available of channels or alternatively in terms of the number of users (subscribers) that the system will support [7].

9. Calculation of the blocking probability (P_B):

The blocking probability is defined as; the probability that a new user finds all channels busy in a certain cell which can be calculated using ***Equation XII appendix I.***

10. Augmented Channel Occupancy (ACO) Matrix:

In the LP-DDCA scheme, each base station assigns channels to calls using the ACO matrix [Fig.4 (B)] which contains necessary and sufficient local information for the base station to make a channel assignment decision.

The content of the ACO matrix table is updated by collecting channel occupancy information from interfering cells. Whenever a change of channel occupancy happens in one cell, the base station of the cell informs the base stations of all the interfering cells regarding the change in order to update the information in the local ACO matrices.

11. Simulation program:

The usage of the computer simulations in this study was highly significant in order to precisely evaluate the total system performance including; the system capacity, the blocking probability and dropping probability of a call.

The experimental simulation program was integrated in to MATLAB (7.1) and was used to evaluate the performance of the proposed LP-DDCA strategy as compared to FCA strategy in terms of blocking probability (which is given in the equation V in the appendix I) versus the increasing percentage of the load per cell.

The simulation program parameters are shown in Table II.

Number of cells	**19 (selected)**
average **holding time**(sec)	55 (real)
average **dwell time**(sec)	300 (calculated)
average speed(km/hour)	55 (estimated)
call arrival rate(call/hour)	3 (real)
initial number of users	12118 (real)
simulation time (hour)	1 (typical)
simulation step(sec)	10 (typical)

Table II. The simulation program parameters

Holding time of a call**:** is the amount of time that the call would remain in progress if it continues in completion without forced termination due to handoff failure.

Dwell time: is the time in the mobility model which spent by each individual subscriber in the calling mode in its serving cell before he moves outside that cell.

The program runs with an initial distribution of users as shown in Table II and then the simulation program increases the number of the subscribers at each cell by 10% until it reaches 50% increment over the initial distribution.

<u>The experimental simulation used in this study consists of three parts;</u>

The preparation (input) part, the main loop part and the output part.

In the preparation part, several pieces of information needed for the simulation were introduced, such as the cell layout or traffic parameters, before the main loop is started.

The main loop is then activated with preliminary finish time (time end), throughout the entire loop, the status of present users is checked and, if necessary, renewed in short time interval the period "time step" several status indicators are successfully stored in matrix "Idinfo".

In every time period in the loop, each user causes several events, such as; call initiation, channel searching, channel allocation, channel re allocation, and call termination based on the status matrix in a time period.

Fig.4 shows the flow chart of the main simulation program.

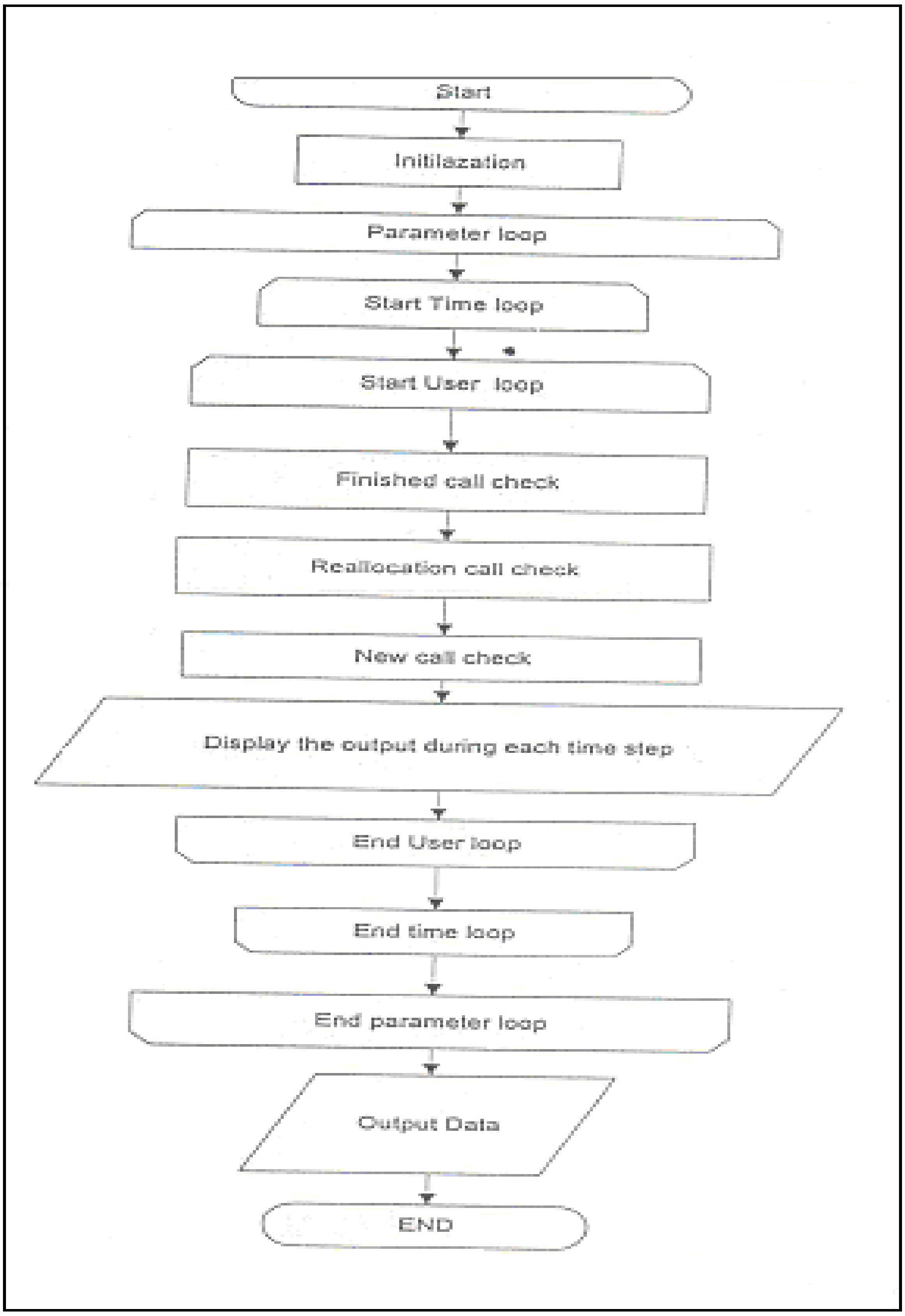

Figure.4: The Flow chart of the main Simulation Program.

The flow charts of the simulation subprograms which were used in both FCA and LP-DDCA schemes are shown in Fig.5 (A) and Fig.5 (B) respectively.

Hand Over: is the transfer calls that are already in progress from one cell site controller to another as mobile units move from cell to cell within the cellular network [10].

Blocking*:* is a loss of a call [10].

Dropping (Handoff)*:* is the interruption would occur in a connected call before its conclusion (or finished).

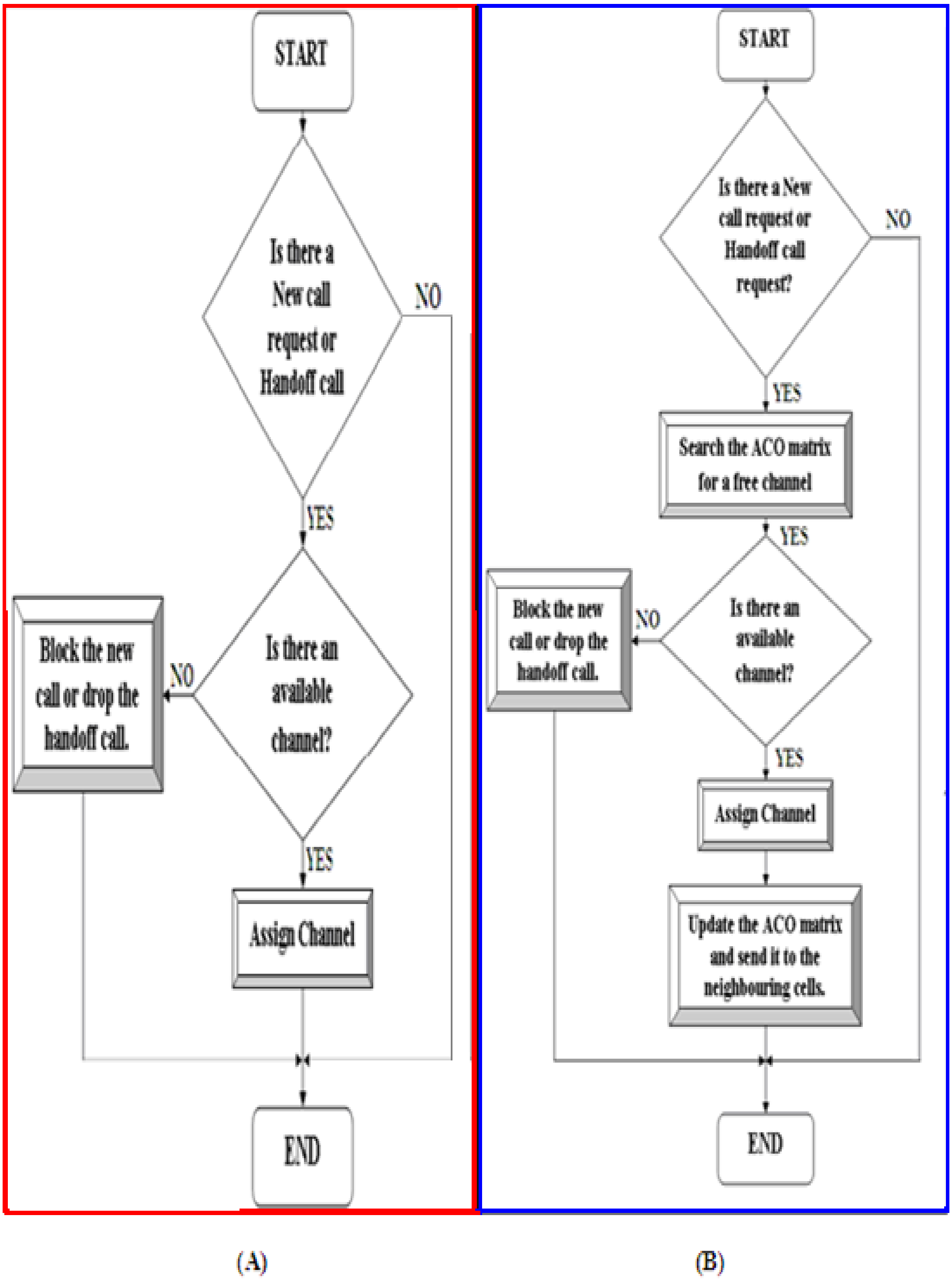

Figure 5: (A): The flowchart of the FCA strategy implementation subprogram. (B): The flowchart of The Distributed DCA Local Packing (LP-DDCA) strategy implementation subprogram.

III. EXPERIMENTAL SIMULATION RESULTS

The calculated results of all tested cells included in the experiment are shown in Table III.

Name of cell	Offered traffic(Erlang)/cell*	Number of users/cell**	Radius (Km)***	Reuse Dist.(km)****
TRP06A	21.45	468	1.74	3.48
TRP52A	19.74	431	1.51	3.02
T5130A	15.98	349	2.48	4.96
TRP53A	8.70	190	1.66	3.32
TRP06B	14.42	315	1.74	3.48
TRP54C	12.70	277	1.66	3.32
TRP51B	16.56	362	1.66	3.32
TRP60B	6.91	151	1.63	3.26
TRP52C	10.76	235	1.80	3.60
TRP52B	18.94	414	1.51	3.02
T5130C	20.24	442	2.53	5.06
T5130B	22.36	488	2.50	5.00
TRP53C	14.10	308	1.75	3.50
TRP53B	9.92	217	1.73	3.46
TI07C	29.77	650	1.91	3.82
TRP54B	14.96	327	1.66	3.32
TRP54A	15.63	341	1.65	3.30
TRP51A	4.19	91	1.62	3.24
TRP60A	7.05	154	1.65	3.30
TRP60C	3.22	70	1.67	3.34
TI08A	8.33	182	1.97	3.94
TI08B	25.05	547	1.97	3.94
TRP55A	6.56	143	1.64	3.28
TRP55B	13.86	303	1.66	3.32
T5127B	12.89	281	2.02	4.04
TRP63C	13.65	298	1.65	3.30
TRP63B	11.44	250	1.66	3.32
TRP628	5.27	115	1.68	3.36
TRP62A	9.70	212	1.64	3.28
TI07B	19.63	429	1.92	3.84
TI07A	31.80	694	1.90	3.80
TRP47C	19.02	415	1.63	3.26
T5119C	16.77	366	1.51	3.02
T5138B	18.10	395	1.64	3.28
T5138C	20.14	440	1.63	3.26
T5117B	7.57	165	1.71	3.42
TRP01A	28.02	612	1.55	3.10

Table III. The selected cells and their measured parameters. *Offered traffic per cell, **Number of users per cell, ***R= Cell Radius, ****D=Reuse Distance.

These results include ; the offered Traffic, the number of users at each cell, the cell radius and the resulted minimum actual Frequency re-use (Co-Channel) distance that satisfy the minimum CIR (CIR_{min} =9dB).

It is found that the resulted minimum actual Frequency Re-Use Distance (D) for each cell that satisfy the CIR_{min} Equal 9 dB will be twice of the cell radius (R) of the corresponding cell.

Fig.6 shows the resulted blocking probability variation as a response to the load increasing of each cell for the FCA and the LP-DDCA at cellular base station.

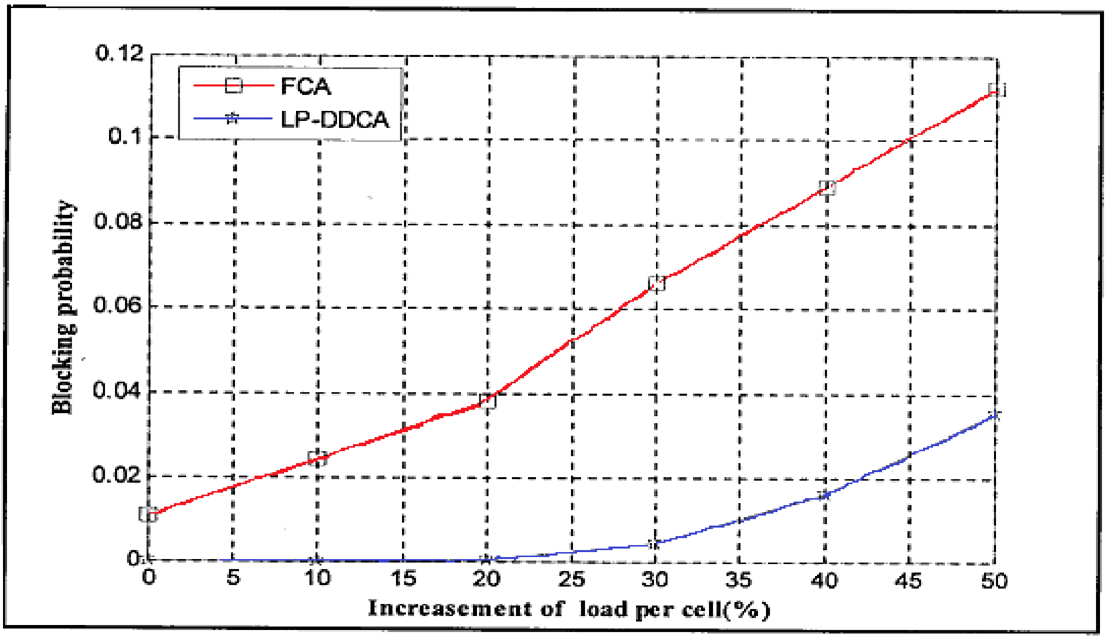

Figure.6: The Blocking probability Vs increase in load/cell for Fixed Channel Allocation (FCA) and Local Packing-Distributed Dynamic Channel Allocation (LP¬-DDCA) Strategy.

IV. DISCUSSION

Channel allocation strategies provide the means to efficiently access the resource of each cell and how to assign the available resource to achieve the highest spectrum efficiency. The channel allocation strategy is the technique which is used to make the most efficient and equitable use of available radio spectrum.

In the networks discussed in the literature [12] [13], the limited radio band is divided into several channels, and these channels are allocated to the subscribers dynamically according to their call request. Certainly, the call request made by a certain subscriber will be abandoned if there are no any idle channels available in the channel resource pool. The DCA strategy that has good performance can substantially reduce the probability of this abandonment (the blocking probability).

The LP-DDCA scheme was selected for this study because the distributed schemes are attractive implementation in microcellular systems which have shown great potential for capacity improvement in high density personal communication networks (including this of interest).

This investigational study has demonstrated that the LP-DDCA strategy due to its flexibility in channel assignment can handle traffic load 35% more than FCA strategy under 0.02 GOS with this improvement (the possibility of increasing load without affecting the quality of service) Al-Madar company can add increase the traffic load by 35% more than FCA under 0.02 GOS and thus adding 4241 subscribers to the selected area of the interested region. Furthermore if this improvement would be generalized to the whole network (300,000) then the network can add 105000 new subscribers.

These results are in high accordance with the related academic literature [13] by demonstrating substantial enhancement of the performance of the tested Al-Madar network by application of the LP-DDCA algorithm scheme.

It is clear from Fig.6 that this study has successfully demonstrated that the usage of the (LP-DDCA) strategy by Al-Madar Company will be exceptionally superior to the currently used FCA strategy.

V. CONCLUSION

The results of this investigational experimental study have proved that the capacity of any cellular system which uses the FCA strategy can be significantly improved by using the LP-DDCA strategy to obtain the optimum possible channel usage utilization.

Furthermore, the results confirm that the adoption of the LP-DDCA scheme could be considered as the elegant solution which can be used by Al-Madar Company in order to efficiently cope with the rapidly growing demand for the digital mobile telephony in Libya.

The application of the LP-DDCA by Al-Madar could substantially enhance the system working capacity of the exciting network and it could make this target viable; technically and economically. Furthermore, it could reduce substantially the required capital expenditure.

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Appendix I

Name of cell	Carried traffic(Erlang)/cell	No. TRU*	No.TCH**	Average Number of Users per Km^2
TRP06A	21.02	4	28	49
TRP52A	19.35	4	28	60
T5130A	15.66	4	28	18
TRP53A	8.53	4	28	22
TRP06B	14.13	4	28	33
TRP54C	12.45	4	28	32
TRP51B	16.23	4	28	42
TRP60B	6.77	4	28	18
TRP52C	10.54	4	28	23
TRP52B	18.56	4	28	58
T5130C	19.84	4	28	22
T5130B	21.91	4	28	25
TRP53C	13.82	4	28	32
TRP53B	9.72	4	28	23
TI07C	29.17	6	44	57
TRP54B	14.66	4	28	38
TRP54A	15.32	4	28	40
TRP51A	4.11	4	28	11
TRP60A	6.91	4	28	18
TRP60C	3.16	4	28	08
TI08A	8.16	6	44	15
TI08B	24.55	6	44	45
TRP55A	6.43	4	28	17
TRP55B	13.58	4	28	35
T5127B	12.63	4	28	22
TRP63C	13.38	4	28	35
TRP63B	11.21	4	28	29
TRP628	5.16	2	12	13
TRP62A	9.51	2	12	25
TI07B	19.24	6	44	37
TI07A	31.16	6	44	61
TRP47C	18.64	4	28	50
T5119C	16.43	4	28	51
T5138B	17.74	4	28	47
T5138C	19.74	4	28	53
T5117B	7.42	6	44	18
TRP01A	27.46	6	44	81

Table I. The selected cells and their related information [5]. *TRU= Traffic per User, **TCH =Traffic Channel.

Equation V:

The calculations of the offered Traffic can be done by using the following equation;

$$\boldsymbol{Offered\,Traffic/Cell = (Carried\,traffic\,per\,cell)/(1 - Blocking\,Factor/Cell)} \quad \textbf{(V)}$$

Where:

Offered traffic /cell*:* is the actual amount of traffic attempts on each cell in the net work of the selected region in the Erlang unit.

Carried traffic /cell*:* is the traffic that is actually serviced by telecommunication equipment in each cell of the net work of the selected region, and it is given by actual measurement in each cell taken by Al-Madar Company in the Erlang unit.

Blocking factor: is also called Grade of Service (GOS), and it is defined as the probability that calls will be blocked while attempting to seize channels in each cell of the network of the selected region, a typical value which is used for this is 0.02 [5].

Equation VI:

$$\boldsymbol{Number\,of\,Users/Cell = (Offered\,Traffic\,per\,Cell)/(Offered\,Traffic\,per\,User)} \quad \textbf{(VI)}$$

Where:

Offered Traffic per cell*:* which is calculated in step (A)

Offered Traffic per user*:* is given as average value of 0.0458 Erlang by Al-Madar Company data [5]

Equation X:

$$\boldsymbol{Average\,User\,Density = Number\,of\,Users\,per\,Cell/\pi R^2} \quad \textbf{(X)}$$

Where;

Average user density: is the average user number per Km^2, and it is given by Al-Madar Company [5].

R: is the cell radius (Km)

π: is the constant =3.14

Equation XI:

$$\left(\frac{C}{I}\right)_{db} = 10\,Log\left(\frac{1}{K_I} \times \left[\frac{D}{R}\right]\right)^{\gamma} \quad \textbf{(XI)}$$

Where:

$\left(\frac{C}{I}\right)_{db}$ →is the CIR within a cell in decibel, and its value which is used here the CIR_{min} =9 dB as given by Al-Madar company [5].

K_I →It is the number of frequency re-use (Co-Channels) cells interfering in the first tier (the interference of the second tier of co-channel cells can be neglected), for a fully developed cellular system based on hexagonal model, there will be six interfering cells in the first tier of surrounding clusters [5].

γ →It is the propagation path loss factor, it is found that in the cellular environment a more appropriate value is γ=4, and if γ=4 it can be assumed that the interference due to cells in the second tier can be ignored [5].

D [the frequency re-use distance (Km)] →It is the resulted minimum actual Frequency re-use distance that satisfy the CIR_{min}=9dB

R *[Cell Radius (Km)]* → It is the cell radius (Km) which has been calculated in Equation X according to the average No. of users per Km^2.

Equation XII:

The blocking probability P_B is given as follows;

$$\boldsymbol{P_B = (B_c)/(C_n)} \quad \textbf{(XII)}$$

P_B → it is the blocking probability (which is defined as the probability that a new user finds all channels busy in a certain cell)

B_c: the number of blocked calls.

C_n: the number of new calls.