Performance and Resource Management of Concentric Cells by Means of Nominal Load Space in Cellular Wireless GSM Networks

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Abstract

GSM (Global System for Mobile communications) operators have only a limited number of channels and therefore, capacity of the network is an important issue and should be optimized in order to meet the requirements of the users. Improving the capacity of GSM systems, will positively affect the capacity of the new generation of mobile networks (i.e. 3G and 4G) because the infrastructure of the 2G will be used as a base for the infrastructure for the future generation. A model of concentric cell approach, which is suggested by Motorola, is presented in this paper to improve the capacity of GSM systems by 10-30 %, in addition to the improvement of the capacity provided by the Synthesizer Frequency Hopping (SFH) approach. The blocking/loss probability of the network is derived and calculated such that the blocking/loss probability meets at least the operators' demands at all locations in the cellular network (i.e. < 2%). The numerical results are given to show that the blocking/loss probability of the outer zones is more critical than the inner zone, however, the blocking/loss probability of the inner zone is always below the limit while the resources of the network are not used very effectively. This problem is solved in this paper by suggesting the reservation policy, where all resources of the network are used very effectively while maintaining the blocking/loss probability within the limit to all zones. Different parameters that affect the performance are presented and discussed, such as; the reservation policy, the ratio of moving mobiles, the coverage and the speed of the mobile in different downtown areas. The curves for the loss probability and the utilization are shown to demonstrate this effect. For verification of the obtained results, some of these curves are validated against real data taken from Ericsson AB, Jordan Branch.

Keywords: GSM Networks, Capacity, Cellular Networks, Resource Management, MOSEL-2 language, Concentric Cells.

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Introduction

GSM (Global System for Mobile communications) is the most popular standard for mobile phones in the world. However, this technology still has deficiencies with respect to the capacity. Mobile operators are facing the challenge of providing customers with better quality-of-service and applications without installing new base station sites. Therefore, the network should be designed properly in order to meet the requirements of the capacity by the users. There was an intensive research in the literature regarding this issue being carried out using different approaches. Various authors [1-7] have suggested a variety of solutions to solve this problem, but most of these techniques required allocating new bandwidth or installing new hardware or base stations. The concentric cell approach is well-known approach to increase the capacity of a cellular network without allocating additional bandwidth or installing new base station sites. Telegraphic analyses have shown that there is a loss in Erlang-capacity when the pack of traffic channels is split into smaller packs, which are assigned to layers. This loss is based on degradation in the trunk of the efficiency. As the trunk is split into smaller packages, not all lines are connectable from all cell locations; there will be an obvious capacity loss. On the other hand, the geographical split into concentric zones allows reusing the frequencies more dense for the inner zones. For this reason, the inner zones need less bandwidth than the outermost zone. As savings in bandwidth replaces the capacity loss, there is a gain in the capacity by splitting cells into concentric zones.

Fig. 1 shows an example of a cell split into three zones. We define a layer $i$ to cover the cell area from zone $i$ to the inner-most zone. The given concentric zone model in Fig. 1 may represent a real life example with the following specifications:

1. Zone 1 may represent:
   - customer zone (Suburbs) or
   - Residential zone (Single Family Homes, Yards/Garages, etc…..)

2. Zone 2 may represent:
   - Transitional Zone:(Recent Immigrant Groups, depreciated Housing, Factories, abandoned Buildings) or
   - Working Class Zone: (Single Family residence).
3. Zone 3 may represent:

- Central business area.

Fig. 1: Cell split into layers and zones (3 zones example)

The rest of the paper is organized as follows. Channel Allocation schemes are discussed in the next section, followed by the explanation of the nominal load space where the blocking/loss probability is derived. Afterwards, the mathematical model is presented followed by the numerical solution of the model by MOSEL-2 language and the introduction of a simple call admission control algorithm. Next to it, the numerical results are presented and discussed. Finally, the conclusions and future work is presented followed by the Acknowledgments.

Channel Allocation Schemes

Channel allocation schemes are required in cellular wireless networks to assign channels or frequencies to the wireless cell in a suitable way to avoid co-channel interference among nearby cells. Different approaches are suggested in literature to assign the bandwidth to the cells in an efficient way while minimizing the interference among the users in the same cell as well as the neighboring cells [8-10]. The common objective of these papers is to achieve higher efficiency of the resources. However, they did not concentrate on maintaining good QoS in the network, which is the objective of the work in this paper. Additionally, the available spectrum to the users is limited;
therefore, it should be used efficiently to ensure that all users receive service while achieving the quality of service of the network. Concentric cell approach is suggested by Motorola [11]. It is a software-enabled feature that allows greater frequency reuse within the inner zone of the cell, allowing more carriers per cell. Frequencies within each concentric cell are isolated to avoid interference with the outer zone. According to Motorola, this approach offers a 10-30 percent increase in the capacity in addition to the 80 percent increase that Synthesizer Frequency Hopping (SFH) provides. The work in [5] was about concentric zones but with respect to the spectrum efficiency index to maximize the capacity of the network. On the other hand, in this paper, the concentric zones approach is used by means of nominal load space to derive the loss/blocking probability. Additionally, new mobility model is suggested in this paper, where three speed values are used to represent real life situation in the downtown area of the city. Furthermore, new parameters that affect the performance are discussed in this paper; such as: coverage, ratio of moving mobiles, reservation policy and the speed of the mobiles. The numerical results are validated against real data obtained from Ericsson AB Company in Jordan.

**Nominal Load Space**

By introducing the concentric cell split approach, some grades of freedom is gained because the coverage area of the layers is now adjustable. The nominal load defined as the amount of offered traffic for which we expect a certain blocking probability. To guarantee a minimum GoS (Grade-of-Service) at all locations, the blocking probability in each zone should not exceed the operators demand (e.g. $P_\text{0} < 2\%$). Assuming constant traffic density over the whole network area, the amount of traffic $T_i$ which is offered to a zone $i$ is proportional to its covered area. The nominal load space $X_\theta$ is defined to be the vector space of zone $(T_1,...,T_L)$ for which the demanded blocking prosperity $P_\text{0}$ is not exceeded at any location in the network.

Generally $M = (m_1,...,m_L)$, (where $L$ is the number of layers) is denoted as the vector of traffic channels which are assigned to each layer, respectively. In the simple channel assignment scheme, it is assumed that each zone can allocate all resources which are available in the layers that cover this zone. Obviously, only the innermost zone can use the resources of all layers (see Fig. 1). Cell states are described in terms of the number of active calls in the zones as a Markov-process. The number of active calls in
the zones is defined by $K = (k_1, \ldots, k_L)$. The possible Markov states can be defined as a set of $L$-tuples,

$$S_M = \bigcap_{i=1}^{L} \{ (k_1, \ldots, k_L) \in N_0^L \mid \sum_{j=1}^{i} K_j \leq \sum_{j=1}^{i} m_j \} \quad \ldots \ldots \quad (1)$$

The states from which the blocking events of the respective zone $i$ occur are defined as follows,

$$B_{i,M} = \bigcup_{n=i}^{L} \{ (K_1, \ldots, K_L) \in S_M \mid \sum_{j=1}^{n} K_j = \sum_{j=1}^{n} m_j \} \quad \ldots \ldots \quad (2)$$

Next the state probabilities can be written as,

$$P_{(k_1, \ldots, k_L)} = P_{(0, \ldots, 0)} \cdot \prod_{i=1}^{L} \left( \frac{T_i^{k_i}}{K_i!} \right) \quad \ldots \ldots \quad (3)$$

With probabilities of the zero state $(0, \ldots, 0)$ chosen in that way, that the sum of all state probabilities is equal to one,

$$\sum_{S_M} P_{(k_1, \ldots, k_L)} = 1 \Rightarrow \text{then } P_{(0, \ldots, 0)} = \frac{1}{\sum_{S_M} \left( \frac{P_{(k_1, \ldots, k_L)}}{P_{(0, \ldots, 0)}} \right)} = \frac{1}{\sum_{S_M} \left( \prod_{i=1}^{L} \left( \frac{T_i^{k_i}}{K_i!} \right) \right)} \quad \ldots \ldots \quad (4)$$

The blocking probabilities in the zones are,

$$P_{b,i} = \sum_{B_{i,M}} P_{(k_1, \ldots, k_L)} \quad \ldots \ldots \quad (5)$$

Respectively from equation (2),

$$B_{i+1,M} \subseteq B_{i,M}, 1 \leq i < L$$
From this property, one can derive the following inequality

\[ P_{b,i} \geq P_{b,i+1}, \quad 1 \leq i < L \]

Simply speaking, the blocking probability in the outer most zone (zone 1) is the most critical one. With the above calculations, it is possible to calculate the blocking probability of zone 1 for every combination of offered traffic \((T_1, \ldots, T_L)\) and the number of channels \(M\). If the operator is demanding that the blocking probability must not exceed a certain limit (i.e. \(P_0 < 2\%\)), then the nominal load space \(X_0\) is given by:

\[ X_0 = \left\{ (T_1, \ldots, T_L) \in R_{0,+}^L \mid P_{b,1} = P_0 \right\} \]

Where \(R_{0,+}^L\) is the set of all positive real numbers \(\leq L\).

**The Mathematical/Analytical Model**

Let the number of active calls in zone \(i\) be given by \(K_i, i \geq 0\). At any instant in time \(t\), the state of the system can be described by a vector \(V_t = \{K_1, \ldots, K_L\}\) where \(L\) is the number of zones in the system. For \(L = 2\) we have \(V_t = \{K_1, K_2\}\) where \(K_1\) and \(K_2\) are the number of active calls in zone 1 and 2 respectively. From a given present state \(V_t\), the system transits to a successive state \(V_{t+1}\) which is entirely dependent on the transition rules and at a rate determined by the occurring event causing change in the state. For example (from Table 1) the arrival of a new call to layer 1 as an event, takes the system into the successive state at rate \(\lambda_{1} + \lambda \cdot \text{hor}\). Table 1 shows the events, rules and transition rates from which a matrix of transition rates \(Q\) can be formulated.

A two dimensional Markov model with a finite state space results from the considered states and transitions and is homogeneous, irreducible and has a unique steady state distribution \(P = \{ P_x \}, \quad x = 0 \ldots M-1\). Where \(M\) is the size of the finite state space, assuming that the states are conveniently ordered from 0... \(M-1\).
Table 1: Transitions from state $V_t$ showing events, conditions and rates

<table>
<thead>
<tr>
<th>Event</th>
<th>Condition</th>
<th>Successive state</th>
<th>Transition</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Call arrival to $L_1$</td>
<td>$K_1 &lt; N_{ch_1}$</td>
<td>$K_1 +1, K_2$</td>
<td>$\lambda_1 + \lambda_2$ hor</td>
<td></td>
</tr>
<tr>
<td>Call arrival to $L_2$</td>
<td>$K_2 = N_{ch_2}$ and $K_1 &lt; N_{ch_1} - R$</td>
<td>$K_1, K_2+1$</td>
<td>$\lambda_2$</td>
<td></td>
</tr>
<tr>
<td>Movement of mobile from $L_2$ to $L_1$</td>
<td>$K_1 &lt; N_{ch_1} - R$</td>
<td>$K_1 +1, K_2$</td>
<td>$K_2 * \mu_{in_out}$</td>
<td></td>
</tr>
<tr>
<td>Movement of mobile from $L_1$ to $L_2$</td>
<td>$K_2 &lt; N_{ch_2}$</td>
<td>$K_1, K_2+1$</td>
<td>$K_1 * \mu_{out_in}$</td>
<td></td>
</tr>
<tr>
<td>Call termination from $L_1$</td>
<td>-</td>
<td>$K_1 -1, K_2$</td>
<td>$K_1 * (\mu + \lambda)$ hor</td>
<td></td>
</tr>
<tr>
<td>Call termination from $L_2$</td>
<td>-</td>
<td>$K_1, K_2-1$</td>
<td>$K_2 * \mu$</td>
<td></td>
</tr>
</tbody>
</table>

We solve the matrix equation $P \cdot Q = 0$, subject to: $\sum_{x=0}^{M-1} P_x = 1$, to obtain the steady state probabilities $P_x$, $x = 0 .. M-1$, from which the performance measures of interest are calculated from the following:

- The mean of layer 1 is : $\text{Mean}_{-L1} = \sum K^1 \cdot P(V_i)$ where $V_i = \{K_1, K_2\}$

- The mean of layer 2 is : $\text{Mean}_{-L2} = \sum K^2 \cdot P(V_i)$ where $V_i = \{K_1, K_2\}$

- The utilization of layer 1 : $\text{Util}_{-1} = \text{Mean}_{-L1} / N_{ch_1}$

- The utilization of layer 2 : $\text{Util}_{-2} = \text{Mean}_{-L2} / N_{ch_2}$

- Loss probability of layer 1:

  $\text{Loss}_{1} = \sum_{V_i : K^1 = N_{ch_1}} P(V_i) \cdot \text{Mean}_{-L2} \cdot \mu_{in\_out}/(\lambda + \lambda_2 \text{ hor})$
• Loss probability of layer 2:

\[ \text{Loss}_2 = \sum_{V:K_1,K_2} P(V_i) \times \text{Mean}_L \times \text{P}_{\text{in\_out}}/ (\lambda + \lambda_\text{hor}) \], where,

- \( \text{Nch}_1 \) is the number of available channels (frequencies) in layer 1.
- \( \text{Nch}_2 \) is the number of available channels (frequencies) in layer 2.

• \( \text{hor} \) is the handover ratio, the most common criterion for requesting a handover.

Using the standard channel assignment scheme, the blocking probability of the inner zones is usually below the limit. As the capacity is reached the maximum blocking probability, not all resources were used effectively. The use of resources of the inner zones can be enhanced if one reserves some traffic channels of layer \( i \) for the exclusive use by zone \( i \). The set of possible states is now,

\[ S'_M = \left\{ \left( k_1, \ldots, k_L \right) \in N_{0}^L : \sum_{j=1}^{L} k_j \leq \min\left\{ \sum_{j=1}^{L} m_j - r_{i-1} \right\} \right\} \] ........................ (7)

Where \( (r_1, \ldots, r_{L-1}) \) denote the number of traffic channels which are exclusively reserved in the layer \( i \) for the use in zone \( i \), respectively. Additionally, \( N_{0}^L = \{\text{the set of all integer numbers}\} \cup \{0\} \) that are less than or equal to \( L \). Therefore, the states from which blocking events may occur are,

\[ B'_{L_M} = \left\{ \left( k_1, \ldots, k_L \right) \in S'_M : \sum_{j=1}^{L} k_j = \sum_{j=1}^{L} m_j \right\} \bigcup \left\{ \left( k_1, \ldots, k_L \right) \in S'_M : i > 1, k_i < \sum_{j=1}^{L} m_j - r_{i-1} \right\} \] ........................ (8)

In opposite to the standard channel assignment scheme, the capacity of the proposed scheme is not limited by the outermost zone only, furthermore, it is possible to adjust the network such that the blocking probability meets the operators demand to all zones.

**The Numerical Solution by MOSEL-2 Language**

**Modelling Assumptions**

The following modelling assumptions are considered:
One cell is considered in the investigation. However, the model can be applied to more than one cell.

The investigated cell is divided into two zones/layers where 8 GSM channels/frequency is assumed for each zone. The total number of frequencies (channels) in the cell is 16.

The new call arrival is assumed to be Poisson with rate $\lambda$ and uniformly distributed over the whole cell.

The incoming handover is assumed to be Poisson with rate $\lambda h$.

The call holding time is assumed to be Poisson with rate $\mu$.

The cell contains moving and non-moving mobiles. The ratio of moving mobiles is $rm$.

The mobile station is assumed to move uniformly with a random direction.

The handover rate is resulting from the movement of the mobile. This rate is computed taken into consideration the following parameters: the speed, the ratio of moving mobile, the coverage, $\lambda_{\text{handover}}$ and cell radius. This time is assumed to be exponentially distributed random variable with rate: $\mu_{\text{in\_out}}$ and $\mu_{\text{out\_in}}$.

The model is solved numerically using MOSEL-2 language [12-14], assuming 2 layers/zones and the numerical results are generated using IGL interpreter which is associated with MOSEL-2 language. The model in Fig. 1 above can be described in MOSEL-2 language as it is shown in Fig. 2. Please note that the line numbers are not a part of MOSEL-2 language but they are used only for referencing to the code (see Fig. 2, the comments are not numbered). MOSEL-2 program is divided into six main parts:

1. **Constant and parameter** part (lines 1-13). This part is used to give a given value to a constant variable and a set of values to a parameter variable.

2. **Node** part (lines 14-15). This part is used to define the nodes in the system. In our system, we have two nodes: L1 and L2, corresponding to layer 1 and layer 2.

3. **Function and condition** part. (this part is not used in this program).

4. **Rule** part (lines 16-23). This part represents the transition states of the system.
5. **Result** part (lines 24-29). The performance measures of the system under consideration are computed in this part.

6. **Picture** part (lines 30-39). It is used to visualize the computed performance measures using the Intermediate Graphical Language (IGL), which is associated with MOSEL-2 package. Additionally, comments are written in MOSEL-2 language in a similar way they are used in C++ language (i.e. using // or /*……*/).

```plaintext
// Model of Hierarchical cell structure in Mobile Networks like GSM

/* case WITH MOBILITY and reservation */

/*----- Input Load and Service times ----*/
1. CONST cov := 0.90;
2. PARAMETER lambda := 0.30..0.80 STEP 0.05;
3. CONST lambda_1 := lambda*(1-cov);
4. CONST lambda_2 := lambda*cov;
5. CONST mue := 0.0125; // 1/80 [1/sec]
6. CONST mm := 0.60; /* ratio of moving mobiles */
7. CONST hor := 0.40; /* ratio of new and incoming handover calls */
8. CONST r := 3000; /* 3km cell radius */
/* car in residential area 30 km/h, pedestrian 3 km/h <> car 50 km/h */
9. CONST speed := 0.833333; // speed
10. CONST R := 1, 3; // RESERVATION
11. CONST lambda_handover := lambda * hor;
/* the definition of the mobility model is below */
12. CONST mue_in_out = (2 * speed) / r * (1 - cov) * mm * ((1 - cov) / cov) + mm * lambda_handover * cov;
13. CONST mue_out_in = (2 * speed) / r * (1 - cov) * mm * (cov / (1 - cov));

/*------- NODES -------*/
14. NODE L1[8];
15. NODE L2[8];
/* Events that control the transition rates */

/*------- New arrival -------*/
```
16. FROM EXTERN TO L1 RATE lambda_1+lambda_handover; // outer zone
17. FROM EXTERN TO L2 RATE lambda_2; // inner zone
18. IF (L2 == 8) AND (L1 < 8-R) FROM EXTERN TO L1 RATE lambda_2;
19. IF (L1<8-R) FROM L2 TO L1 RATE L2*mue_in_out;
20. IF (L2 < 8) FROM L1 TO L2 RATE L1*mue_out_in;
21. IF (L1+L2==16-R) FROM L2 TO EXTERN RATE L2*mue_in_out;
/*----- Termination of call and outgoing handover request ----*/
22. FROM L1 TO EXTERN RATE L1 * (mue+lambda_handover);
23. FROM L2 TO EXTERN RATE L2 * mue;
/*----------- RESULTS -----------*/
24. PRINT mean_l1 := MEAN(L1);
25. PRINT mean_l2 := MEAN(L2);
26. PRINT util_l1 := mean_l1 / 8;
27. PRINT util_l2 := mean_l2 / 8;
28. PRINT loss1:=PROB(L1==8)*mean_l2*mue_in_out/(lambda+lambda_handover);
29. PRINT loss2:=PROB(L1+L2==16-R*mean_l2*mue_in_out/(lambda+lambda_handover);
/*------- PICTURES -------*/
30. PICTURE "Blocking1_lambda"
31. PARAMETER lambda
32. XLABEL "lambda"
33. YLABEL "Blocking Probability"
34. CURVE loss2;//curve for the loss probability
//----Utilization----
35. PICTURE "Utilization"
36. PARAMETER lambda
37. XLABEL "lambda"
38. YLABEL "Utilization"
39. CURVE util_l2; //curve for the utilization
/*-End of the Program (model)-*/

Fig. 2: Modelling of the example in Fig. 1 by MOSEL-2 using two zones/layers.
MOSEL-2 program can be edited by using any available text editor (WordPad, TextPad, etc.) and saved under "filename.mos". MOSEL-2 program is installed, compiled and executed via LINUX operating system using the following command line:

```
> mosel2 -option filename.mos
```

The option "-option" gives MOSEL-2 the option to translate the model to a specified evaluation tool: (i.e. "-cs" for SPNP [15, 16], "-ms" for MOSES [15], or "-Ts" for TimeNet [15, 17]). If the MOSEL-2 program is compiled successfully without any mistakes, then MOSEL-2 will generate two output files (result file: "filename.res") and (igl file: "filename.igl"). At this stage, one can browse the results of the performance measures by using the following line command:

```
>igl filename.igl
```

Additionally, the performance measures that are computed in the "result" part and described in the "picture" part, can be visualized graphically using the following line command:

```
>more filename.res
```

By using the IGL interpreter, which is associated with MOSEL-2 package, it is possible to modify and export the generated figures into different forms to satisfy the user needs via a very friendly environment.

The coverage factor in the inner-most zone is used to derive the arrival rate to each zone according to the following equation:

\[
\lambda_1 \text{ (zone 1)} = (1-cov) \lambda \text{ (line 3 in Fig. 2)},
\]

\[
\lambda_2 \text{ (zone 2)} = (cov) \lambda \text{ (line 4 in Fig. 2)}.
\]

The default values for the coverage factor are mentioned in Table 2. The assumed mobility model works very well with our assumptions and it takes into consideration very important parameters that affect the performance. The following mobility model is
used in the numerical solution, which represents the rates for the movements for zone 1 to zone 2 and vice versa:

\[ \mu_{\text{in\_out}} = \frac{2 \times \text{speed}}{r \times (1 - \text{cov})} \times \text{rm} \times \left(\frac{(1 - \text{cov})}{\text{cov}} + \frac{\lambda_{\text{handover}} \times \text{cov}}{\text{cov}}\right) \] (line 13 in Fig. 2).

\[ \mu_{\text{out\_in}} = \frac{2 \times \text{speed}}{r \times (1 - \text{cov})} \times \text{rm} \times \left(\frac{\text{cov}}{1 - \text{cov}}\right) \] (line 14 in Fig. 2).

Where,

- \( \mu_{\text{in\_out}} \) is the rate of moving from the inner zone to the outer zone.
- \( \mu_{\text{out\_in}} \) is the ratio of moving from the outer zone to the inner zone.
- Speed is the speed of the mobile (3 values for the speed are assumed: 3 km/h, 30 km/h, 50 km/h).
- \( \text{rm} \) is the ratio of moving mobiles.
- \( \text{cov} \) is the coverage factor of the inner-most zone.
- \( \lambda_{\text{handover}} \) is the rate for the incoming handover calls to the cell = \( \lambda \times \text{hor} \). Where
- \( \text{hor} \) is the ratio of new and incoming handover calls.

The mobility model is used to reflect the movement in the downtown. Three types of speed are used to reflect this movement. Walking speed (3 km/h), vehicle speed in residential area (30 km/h) and vehicle speed in in-city main streets (50 km/h). The following call admission control algorithm controls the admission of the user to the target zone/layer.

**Call Admission Control**

**Step 1.** There is an arrival to each layer \( (i, j \) and \( k \) \) calculated according to the coverage, as given in Table 2 (an example for 2 layers is given), with rate \( \lambda_{1} \) to layer \( i \) and \( \lambda_{2} \) to layer \( j \) and so on.

**Step 2.** If there is a call comes to the inner most layer, \( i \) but the number of channels in this layer are all occupied, the call is transferred to the outer or outer most layer, of course, if there is reserved channels for layer \( j \) to be used by zone \( j \), otherwise the call is lost.
Step 3. IF there is a call comes to the outer or outer-most layer \( j \) then this call should be served either by the channels that are available to this layer (i.e. layer \( j \)) or by the reserved channels in this layer. If there are no resources available in both cases, then the call is lost.

Step 4. After service, the call moves either from layer \( i \) or layer \( j \) to outside.

Numerical Results

The numerical results are produced using MOSEL-2 language. The default parameters are given in Table 2. For simplification, the results are generated using 2 layers/zones model, however, the numerical results can be applied to any number of layers/zones. The results of the loss probability and the utilization are shown with and without the reservation policy. The generated results are based on different scenarios. The first group of results is with and without using the reservation policy. However, the reservation policy is included in the rest of the results. For validation of the results, the curves in Figs. (3-6) and Figs. 11 and 13 are compared with real data taken from Ericsson AB Company in Amman, Jordan as they are applying somehow similar model to the suggested model in this paper. However, the data given is an average real data and it is changeable from one environment to another, additionally, the network behavior on special events is also changeable because different parameters are affecting the behavior of this type of systems. The second group of results is based on the coverage. The third group is based on the ratio of the moving mobiles and the forth group is based on the speed of the mobile.

Adopting the model suggested in this paper by network operators will increase the capacity of GSM network by 10-30 % \cite{11}. Although there is some cost for building the infrastructure of the network, the benefits for network operators will be maximized as less number of base stations is needed. This situation can be explained as: when the loss probability in the network is minimized, the capacity is optimized, and hence more users will share network resources more efficiently and intensively. On the other hand, GSM network infrastructure will be considered as the base and core for the network infrastructure of the new generation of mobile network (i.e. 3G and 4G). The same GSM infrastructure will be used with only additional nodes, which in return, will increase the benefit against the required cost for network operators.
Reservation policy

Figs. 3 and 4 represent the loss probability and the utilization for both zones without using the reservation policy. It can be noticed that the loss probability is high for both zones as well as the measurements of the utilization is not suitable. As the outer most layer is the most critical one, it is important to have low loss probability to this layer (< 0.02) in order to cope with the requirements of the operators. On the other hand, we can notice from Figs. 5 and 6 that the reservation policy (R=5) has a positive effect on the loss probability and the utilization but this effect is noticeable for the outer-most layer than the inner-most layer. As it is well known, the objective of using the reservation policy is to reserve some channels to be used by the outer zone (zone 1). Therefore, the inner zone will suffer from this phenomenon, as some calls that are transferred from the inner zone to the outer zone will suffer from a lack of frequencies. This is due to the reserved frequencies to the sake of the outer zone. This effect can also be noticed from Figs. (7 and 8) where different values of R is considered (R = 1, 3, 5). Therefore, it can be found from Figs. 7 and 8 that the reservation policy has a positive effect on the outer zone (zone 1) whereas it has a negative effect on the inner zone (zone 2). The loss probability of the outer zone is getting better as the number of reserved channels is increased. Regarding the real data, it can be noticed that under the same conditions with and without reservation policy, the proposed model gives better results for both the loss probability as well as the utilization at different call rates. However, as the rate increases (i.e. > 0.80 calls/sec ), the results of the model match the real data. This implies that the suggested model gives good results and hence new parameters that affect the performance are suggested to the operators in the mobile companies to improve the performance of the network.
Table 2: (default parameters)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coverage factor, cov</td>
<td>0.10, ..., 0.90 (variable of study)</td>
</tr>
<tr>
<td>Lambda, ( \lambda )</td>
<td>0.30, ..., 0.90</td>
</tr>
<tr>
<td>The number of reserved channels, ch</td>
<td>1, 3 or 5</td>
</tr>
<tr>
<td>The number of assumed channels/frequency, Nch1 (for zone 1), Nch2 (for zone 2)</td>
<td>8 channels to each layer/zone</td>
</tr>
<tr>
<td>( \lambda_1 ), arrival rate to zone ( 1 )</td>
<td>(1-cov)* ( \lambda )</td>
</tr>
<tr>
<td>( \lambda_2 ), arrival rate to zone ( 2 )</td>
<td>cov * ( \lambda )</td>
</tr>
<tr>
<td>Call holding time, ( 1/\mu )</td>
<td>100 sec (exponential)</td>
</tr>
<tr>
<td>Cell radius, ( r )</td>
<td>3 km</td>
</tr>
<tr>
<td>Speed</td>
<td>3 km/h, 30 km/h, 50 km/h</td>
</tr>
<tr>
<td>hor (handover ratio)</td>
<td>0.40, 0.60 (variable of study)</td>
</tr>
<tr>
<td>rm (ratio of moving mobiles)</td>
<td>0.25, 0.50, 0.75 (variable of study)</td>
</tr>
</tbody>
</table>

Fig. 3: Loss probability (without reservation)

Fig. 4: Utilization (without reservation)
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Fig. 5: loss probability (with reservation R = 5)

Fig. 6: Utilization (with reservation R = 5)

Fig. 7: loss probability (zone1) for different values of R

Fig. 8: loss probability (zone2) for different values of R

Coverage

In cellular wireless networks, coverage and capacity are closely related. From Figs. (9-12), we can notice that increasing the coverage of the outer zone has a negative effect on the loss probability and positive effect on the utilization for both zones. Therefore, this is an optimization problem and should be taken into consideration by the operators, but of course, it is possible to achieve the required performance, especially for the outer zone (i.e. zone 1). Thus, the performance of zone 1 is better than zone 2 at different traffic loads with respect to the loss probability, however, the utilization of zone 2 is better than zone 1 as zone 1 always suffers from many handovers from outside and from the inner zone as well. However, if we look at the figures of the utilization, we can notice that as the traffic load increases, the cell (zone 1 and zone2) try to achieve
balanced load over the whole cell, which leads to balanced load over the whole network.

Fig. 9: Loss probability (coverage factor-zone 1)

Fig. 10: Utilization (coverage factor-zone 1)

Fig. 11: Loss probability (coverage factor-zone 2)

Fig. 12: Utilization (coverage factor-zone 2)

**Ratio of the moving mobile**

As the ratio of moving mobiles decreases, the loss probability decreases and the utilization decreases as well. This is an expected result as when we have a lot of moving mobiles, the number of handovers will be high which leads to decrease in the performance of the cell. This can be noticed from Figs. (13-16). If we look at Fig. 13 (i.e. loss probability of zone 1), there is a complete match between the suggested model and the real data when the rate is low. As the rate increases, the results of the loss probability rates for the model become better (i.e. lower) than those for the real data. This is important as the cell (i.e. zone 1) behavior becomes critical when the traffic is high. When we look at Fig. 15 (i.e. loss probability of zone 2), and Fig. 16 (i.e. utilization of zone 2), we will notice that the results of the real data are better than those of the model for low rate (< 0.70 calls/sec). When the rate increases (> 0.70), the results of the model
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become better.

**Fig. 13:** Loss probability (ratio of moving mobile)

**Fig. 14:** Utilization (ratio of moving mobile)

**Fig. 15:** Loss probability (ratio of moving mobile)

**Fig. 16:** Utilization (ratio of moving mobile)

**Speed of the mobile**

Figs. (17-20) are the curves that represent the effect of the speed of the mobile on the performance of the cell. The speed values represent three types of speed in the downtown city; 3 km/h for walking speed, 30 km/h for speed in residential area and 50 km/h for main street. It can be noticed from the curves that as the speed of the mobile increases, the performance decreases because the loss probability becomes high and utilization is reduced. As the load increases, the curves for the loss probability and the utilization of both zone 1 and zone 2 become closer and closer for both zones.
This is very noticeable from the curve which represents the utilization of zone 2 (i.e. see Fig. 20). This explain the fact that the suggested model works very well to achieve balanced performance over the whole cell, which leads to balanced performance for the whole network even when the user is on move.

Conclusions and Future Work

The concentric cell approach, which is suggested by Motorola, is presented in this paper by means of nominal load space to improve the capacity of GSM systems. A new channel assignment policy is introduced to improve the efficiency of the model and meet the requirement of the operators (i.e. loss/blocking probability < 2%). It is shown that the resources of the network are used very effectively when the new reservation policy in the outer zone (i.e. zone 1 in Fig. 1 above) is introduced. The presented model and the produced numerical results prove the efficiency of the suggested model to improve the capacity of GSM systems as well as balancing the load over the whole cell, which leads
to balanced load over the whole network. The results of the model are compared with real data obtained from Ericsson AB Company in Jordan. New parameters that affect the performance are presented to be considered by the operators; such as: ratio of moving mobiles, reservation policy, coverage and the speed of the mobiles at different locations in the downtown city. This research work can be extended to include a multi-cell approach. Additionally, a multi-service model (i.e. voice, data and video) can also be introduced to extend the capability of the model to be applied to GSM/GPRS systems, UMTS systems, or even 4G systems.

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References


References
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