Pole Capacity Enhancement Technique in GSM/UMTS Co-Sitting Cell by Introducing Vocoder Parameter


Abstract—Existing GSM networks are being replaced by UMTS/3G networks to meet the increasing demand of wireless communication services. In order to achieve the target capacity and reduce the deployment cost of UMTS/3G, co-sitting mechanism has been proposed and implemented throughout the world. In this paper, a mathematical parameter, vocoder, has been introduced in the existing equation to increase the pole capacity. Proposed approach is justified by the result of 25% increase in pole capacity.

Index Terms—GSM/UMTS co-sitting, network optimization, pole capacity, radio network planning.

I. INTRODUCTION

The technological revolutions and enhancement of wireless cellular communication lead to 3G system which provides high bit rate with multi-service capabilities. A good effort to be spent by the operators to build 3G cellular networks with high system capacity by spending the lowest possible cost. High quality performance with multiservice capabilities is key factors of 3G system. But, at present 2G/2.5G, comparatively with low capacity, low quality services and low bit rate, cellular networks are being extensively used throughout the world. Therefore, to coordinate with 3GPP (3rd Generation Partnership Project) standardization with low deployment cost, GSM/GPRS and UMTS/WCDMA networks need to be merged by sharing the existing GSM network. And this sharing of basic core network elements, network sites, antennas and modules are known as GSM/UMTS co-sitting.

This co-sitting saves the operator major costs such as establishment costs, maintenance costs, site rental and site acquisition cost, etc. A complete study for coverage, capacity and interference issues while reusing the GSM900/1800 sites for UMTS900/1800 are done [1]. UMTS900 can also be co-sited with GSM900 with limited data coverage [2]. In case of UMTS2100, it will need more new UMTS sites due to small coverage area as the signal is propagating by higher carrier frequency. But it is shown that reusing all existing GSM sites with UMTS is not as satisfactory as the performance of UMTS alone in terms of capacity and coverage [3]. But, it is preferred that GSM cell site can be reused in addition to adding new UMTS sites. How to minimize the deploying cost of a UMTS network by reusing the existing GSM sites, which provides the capacity of 40 users per cell using newly added UMTS sites, is shown in [20]. This paper presents an optimum solution that provides 50 users per cell that is almost 25% more than that in [20].

II. LITERATURE REVIEW

UMTS radio network planning are basically depends on coverage, capacity and quality of service. UMTS features such as power control and handover are considerable aspects for network planning. Considering important aspects, mathematical optimization, heuristic analysis and optimization models have been proposed. Network coverage and capacity are important performance indicators which depend on the traffic demand scenario of uplink or downlink. Interference levels are functions of the emitted power which depends on the mobile station positions. Optimization models and configuration for the BS station are depends on signal to interference ratio (SIR) for the uplink and downlink [5] - [7].

Optimization models are relevant with the presence of the asymmetric traffic for downlink direction [8]. Since interference levels depend on the connections within a given cell and neighboring cells, the SIR values and the capacity are highly affected by the traffic distribution in the whole area. Moreover, for the downlink and uplink direction more optimization models are presented in [9] - [12]. The planning phase of cellular networks provides the following kinds of input information related to the service area: 1) a set of candidate sites where BSs can be installed; 2) the traffic distribution estimated by using empirical prediction models; and 3) the propagation description based on approximate radio channel models or ray tracing techniques. The main
The purpose of planning is then to select the sites where to install the BSs taking into account different aspects such as costs, signal quality, and service coverage [7]. Interference limits the amount of traffic served by the system. The spreading factor (SF), which is the ratio between the spread signal rate and the user signal rate. In wireless environments, due to multipath propagation, the interference of orthogonal signals cannot be completely avoided [7].

For equal signal power and equal distance between adjacent BS, a network will be uniform with uniform user distribution. For non-uniform user distribution new cells added in order to form hot spot areas [14]. For maximizing network capacity a simultaneous optimization is done for the pilot signal power and the BS location considering intercell and intracell interference [14].

Coverage analysis, capacity evaluation, radio link budget and finally estimation of number of BS sites are included in the activities of practical UMTS radio network planning. The coverage and capacity are related to each other whereas coverage or cell range are depend on number of simultaneous user a BS can cover. The operator’s link budget analysis tries to meet a targeted cell load to minimize the number of used BSs, and the targeted downlink cell load is depend on traffic requirements [20]. Here dimensioning is done by based on this UMTS property. Studies show that for stable network operation, the downlink cell load should normally not exceed 70% of the pole capacity [15]. In some papers, it is 80% of the pole capacity.

III. UMTS RADIO NETWORK PLANNING

2G wireless networks, in particular the extremely successful and widespread global GSM-based cellular systems, are using throughout the world. The mobile communications industry throughout the world is currently shifting its focus from 2G to third-generation (3G) UMTS technology. For this reason, mobile operators are investing in the design and manufacturing of advanced mobile internet/multimedia-capable wireless networks based on the Wideband Code Division Multiple Access (WCDMA). At the same time, other wireless communication professionals are becoming familiar with WCDMA radio technology and are preparing to build and launch high-quality 3G networks. Radio network planners are trying to deploy 3G services in the 2G GSM system of the underlying WCDMA radio access method. Some of the defining characteristics of 3G multi-service radio networks are summarized in an abstract setting, regardless of the particular incarnation of the underlying 3G radio access protocol, such as WCDMA or EDGE [4].

IV. MATHEMATICAL OPTIMIZATION OF PROBLEMS

To suppress multipath, multiuser interference and differentiate their own signal, user normally depends on channelization and scrambling. Quality of service (QoS) constraints requires the signal to interference ratio (SIR) to exceed a minimum value which depends on the service characteristics. The downlink SIR expression can be, in general, expressed as [20]

\[ SIR = \frac{P_{received}}{\sigma^2 + I_{in} + I_{out}} \]  

Where, \( P_{received} \) is the received signal power, \( \sigma^2 \) is the thermal noise power, \( I_{in} \) is the intracell interference (interference within the same cell), \( I_{out} \) is the intercell interference (interference from neighboring cells), SF is the spreading factor, and \( \lambda \) is the orthogonality factor (0.4 ≤ \( \lambda \)≤0.9). The downlink SIR expression can be further analyzed and expressed for each user as:

\[ SIR_{k} = \frac{SF \cdot g_{k0} \cdot P_{BS,k}}{\sigma^2 + \lambda \cdot g_{k0}(P_{BS}-P_{BS,k}) + g_{k0} \cdot \sigma^2_{BS}} \geq SIR_{MS,k} \]

Where \( P_{BS} \) is the total BS transmit power, \( P_{BS,k} \) is the BS transmit power allocated to mobile station (MS) \( k \), \( g_{k0} \) models the path loss between MS, \( k \) and its BS which is calculated according to Cost 231-Hata model [16], \( g_{k} \) is the intercell to intracell interference factor at MS \( k \), and \( SIR_{MS} \) is the target SIR to achieve the required Quality of Service (QoS) at the MS. Since the SIR depends on the received powers, a power control mechanism is usually applied that dynamically adapts the transmitted power of the BS for each user to meet the required QoS [20].

The number of user in cell that are able to satisfy target SIR is called user capacity and the maximum user capacity is called the pole capacity. Assuming all users belong to the same service class and ideal power control condition, the downlink pole capacity can be calculated as [17]

\[ K_{pole,DL} = \frac{SF + \lambda SIR_{MS}}{\lambda + \sigma^2_{av}/SIR_{MS}} \]

Thus, the pole capacity depends on the spreading factor (SF), the target SIR (\( SIR_{MS} \)), the orthogonality factor (\( \lambda \)), and the average intercell to intracell interference factor (\( \sigma_{av} \)) which varies from 0.1 to 0.8 depending on the cell range and the path loss propagation model [18].

Inputs, outputs, objectives and constraints of the models need to be identified to formulate GSM/UMTS co-siting as an optimization model. Here, we will assume the following the input data : 1) A geographical area described by cartographical information, and traffic demand derived from its topographical information defined by a user density distribution \( \rho(s) \), where \( s = (x, y) \) represents the coordinates of a given point within the area, and \( N_{u} \) represents the number of users, 2) cost of deploying a new site which is greater than the cost of reusing an already existing site by a pre-defined factor that can be configured, 3) a set of BSs whose cardinality is \( N_{BS} \) among which \( n_{new} \) are new BS sites distributed arbitrarily between the \( N_{fixed} \) existing GSM sites [20]. We use Lloyd method which finds the location of the newly added sites in a way that minimizes the variance of the users among the cells but in the iterations of the Lloyd method, the fixed site locations are kept in their positions which might affect the method’s convergence. A cell is represented by the Voronoi region \( v \).

The GSM/UMTS co-siting optimization problem is solved by taking the pole capacity and the fixed site locations into account. If the cell capacity increased then the overall co-siting cost will be decreased. The Lloyd method is summarized as follows:
1. Select an initial set of k points \( \{z_i\}_{i=1}^{k} \)
2. Construct the Voronoi tessellation \( \{V_i\}_{i=1}^{k} \) associated with the points \( \{z_i\}_{i=1}^{k} \)
3. Compute the mass centroids of Voronoi regions \( \{V_i\}_{i=1}^{k} \) found in Step 2; these centroids are the new set of points and are computed as
   \[
   T(z) = \frac{k \sum_i^n s_i z_i}{k \sum_i^n s_i} 
   \]
4. If this new set of points meets some convergence criterion, terminate; otherwise, return to Step 2.

V. RESULT AND ANALYSIS

In this paper, two scenarios will be presented with uniform and non-uniform user distributions. This section presents the results of the optimization problems considering the following simulation parameters: Area \( A=10 \text{ km} \times 10 \text{ km} \) with \( N_u=5000 \) users, and suggested \( K_{pole,DL} \) in [20]

\[
K_{pole,DL} = \frac{SF + \lambda SIR_{MS}}{\lambda + \alpha_{av}} SIR_{MS} 
\]

From [21] for UMTS criteria,

\[
N_{pole,DL} = \frac{\eta_{OH}}{\eta_{t} + \sqrt{\lambda + \alpha}} \frac{W}{R_{B}} 
\] (5)

Here, \( \eta_{OH} \) = overhead channel power = 25% = 0.25; which has a large effect on WCDMA cell.

\[
\frac{E_{p}}{N_{t}} \approx SIR_{MS} ; \\
\frac{W}{R_{B}} = \frac{\text{Chip Rate}}{\text{Bit Rate}} = SF ; 
\]

Replacing these relations in (5)

\[
N_{pole,DL} \approx \frac{(0.75) SF}{\sqrt{V * (\lambda + \alpha)}} ; \\
= \frac{0.75}{\sqrt{V * (\lambda + \alpha)/SIR_{MS}}} 
\]

(6)

Comparing (5) and (6)

\[
K_{pole,DL} = \frac{0.75}{V * (\lambda + \alpha)/SIR_{MS}} 
\] (7)

Here:

\( V = \text{voice coder parameter} = 0.6; SF \approx 315; \lambda = \text{orthogonality factor} = 0.4, \alpha_{av} = \text{interference factor} = 0.55, SIR_{MS} = 7\text{dB} = 5.01 \)

Now, putting these values in (7)

\( K_{pole,DL} = 82.72 \approx 83. \)

And, number of user is 60% of the pole capacity; So, number of user = 49.80 \approx 50.

This is 25% more than that of using with voice coder parameter.

VI. UMTS RADIO NETWORK PLANNING WITHOUT CO-SITTING

We got these Figures by using voronoi tessellation where it use Lloyd method.

Fig. 1 presents the output locations of BSs for the uniform distribution of users, that is \( \rho(s) = \lambda/A \); where \( A \) is the area to be covered. It is obvious that every BS is covering the same area since the user distribution is uniform [20]. Monte-Carlo simulations are used, where in each simulation 5000 users are uniformly distributed across the planned network, to evaluate the average power transmitted foe each BS. Results show that the average powers of the BSs are nearly equal. These results are comparable to [14], which showed that for a uniform distribution of users, the network layout is uniform with nearly equal pilot powers.

Fig. 2 presents a Gaussian distribution of users where output locations, assuming a hot spot model and the user density, are densely situated at the center area and decreases along the way to the border area.
VII. UMTS Radio Network Planning with GSM/UMTS Co-Sitting

For uniform user distribution, the GSM cell range is assumed to be around 900 m. Therefore, around 50 GSM BSs would be required to cover the simulated area [20]. Fig. 5 shows input of 175 BS locations where 50 uniformly distributed GSM sites and 125 arbitrary sites.

To satisfy the confinement of the optimization problem 125 out of 175 BS are required where 39 GSM are reused which is around 78% of the existing GSM sites (the remaining 86 sites are all newly deployed UMTS sites). In Fig. 6, there are 175 BS locations that include 50 normally distributed GSM sites in addition to 125 arbitrary sites where the inputted and optimized output locations of the UMTS BSs are considered for Gaussian distribution of users.

Due to the Gaussian distribution of users over the considered area, the density of the output UMTS sites (co-sited and new) is highest at the area center and decreases along the way to the boundary area.
Fig. 6. Optimal output location of BS (total of 125 BSs with 38 re-used GSM sites) for GSM/UMTS co-siting considering Gaussian distribution of users.

VIII. CONCLUSION

Finally, we have presented a mathematical optimization model to increase the pole capacity of the system ensuring that every UMTS BS is covering a given percentage of the downlink pole capacity. The percentage of GSM site reuse depends on their number and their locations, and it will be better to reuse all the sites.

REFERENCES