General Packet Radio Service Performance Evaluation Considering Adaptive Overlapping

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Abstract- General Packet Radio service (GPRS) is a part of the evaluation path towards 3G. This paper investigates the effect of using adaptive overlapping between adjacent cells on the data sessions within GPRS system. A simulator model was developed to study the behavior of data transmission between a GPRS server and data terminals via air interface. Simulation results show the trustworthiness and validity of the proposed approach even at high offered traffic.

I. INTRODUCTION

Migration from the second generation such as the GSM towards the third generation such as UMTS or CDMA2000 is achieved by a change in the inherent switching technology, from circuit switching to completely packet switching system. This sharp switching technology conversion could be done smoothly via a hybrid system such as GPRS, which considered as 2.5 generation. So it is considered as a key step towards the evolution of the third generation.

GPRS is a standard from the European Telecommunication Standards Institute (ETSI) as a new bearer service based on GSM architecture [1, 2]. The rule of GPRS is to provide a packet switched service in GSM networks. The service providers use the scarce radio resources in a more efficient way. It is assigned on demand. Wireless access to external internet protocol-based network such as internet, provides mixed service capability for both real-time and non real-time applications such as WWW, ftp, email and video conference. GPRS network operator provides subscribers with instant connection “always on connection”, high data rate with theoretical maximum speed up to 171.2 kbit/s by applying Multi Slot Capability (MSC) against 9.6 k bit/s of SMS over GSM networks. Several analytical and simulation models have been proposed to study the performance of GSM/GPRS. In [3] transmission of data packet in the silent periods of a conversation with voice activity detection was proposed. The effect of using dynamic and fixed channel allocation on the GPRS QoS presented in [4]. In [5] different types of queues for mobility management related packets was considered to reduce the delay time by reducing the competition time of the Routing Area Update (RAU). A comparison between using a queue and keeping a dedicated channel for GPRS users is introduced [6]. In [7-9], GPRS performance and capacity evaluation are estimated considering different radio resources allocation strategies. Different from the previous works, the key feature of the proposed approach here is that: a simulator developed in Matlab environment is used to study the effect of overlapping on the GPRS system performance. The simulator focuses on the communication over the radio interface between a MS and BSS, as it is one of the most crucial aspect of GPRS operation, and mainly determines the performance of any wireless network.

II. GPRS NETWORKS

The proposed model is a GSM/GPRS system, in which the GPRS subsystem is a new bearer service designed to be an extension to the GSM network. The GPRS functionalities was achieved by introducing two GPRS support nodes (GSNs), the serving GPRS support node (SGSN) and the gateway GPRS support node (GGSN). The SGSN delivers packets to and from mobile stations within its service area, it detects new GPRS MS and queries the home location register to get user profile, and it keeps track of mobile stations locations. GGSN links different SGSNs and provides interface between GPRS network and other external Internet Protocol based networks such as (internet-other GPRS networks ). GPRS greatly improves the operation of the wireless data communication networks such as; the benefit from the network point of view, is that, it employs packet switching which enables operators to use the limited spectrum more efficiently since the radio resources are used only when users are actually sending or receiving data so that the system capacity increases, while the benefit form the customer point of view, is that the GPRS offers much higher data rate than conventional GSM system by applying MSC, thus enables new and better wireless data applications so that the mobile phones will be changed from the traditional one to a multi media wireless access one.

The GPRS gets its radio resources by sharing the GSM resources. Until now one of the most recent questions is, how to divide the cell capacity between the traditional GSM and GPRS services. In [7, 8] it is found that a more data friendly strategy is, to reserve Q time slots from N time slots in each GSM/GPRS TDMA frame for data connection preventing their use by voice calls , consequently guaranteeing a minimum amount of band width to be shared among all active data connections. The drawback of this strategy is the increase of the number of blocked voice calls due to the reduction in the time slots available for voice. In order to guarantee a fixed voice call blocking probability, it is necessary to dimensioning the cell for a reduced offered voice load, therefore a balance between the reduced number of served voice calls and the required increase of data connections has to be performed by the network operator. The remaining N-Q time slots are shared between GSM and GPRS users with full preemption for the voice call over data connection in this shared partition, so when a voice call arrived and there is no available channel, then the voice preempt a channel used by data connection and the data terminal (GPRS user – data terminal are rechangeable) is forced to stop its transmission (immediately released) and stored in a queue, waiting for service. The GPRS user during its data session will send and receive data, the data sent or received by a user must be converted into bursts, each burst data bits is conveyed by a time slot each frame period. The conversion of data user to burst carried out through multiple levels, at first the data is segmented into packets, each packet is split into Logical Link Control (LLC) frames, each LLC is in turn split into a number of Radio Link Control (RLC) blocks as shown in figure (1). The number of data bits contained in each RLC block depends on the used Coding Scheme (CS1-CS4). The RLC block is the Packet Data
III. PROPOSED APPROACH

This paper focuses on the performance of GPRS data service considering adaptive overlapping between adjacent cells in a cluster of seven hexagonal cells cellular mobile network. The key feature of the presented approach is to show how the adaptive overlapping between adjacent cells can affect the quality of service parameters such as the failure probability of new and handoff attempts of data terminals, the RLC block delay and throughput (channel utilization by GPRS load). Comparison between the proposed approach and previous approaches, shows the validation of the proposed approach. The existent of adaptive overlapping will affect the Carrier to Interference Ratio (CIR) between co-channel cells, CIR is a crucial parameter in today’s network, as the capacity of any wireless network is interference limited, as shown in figure (2), where an ideal seven hexagonal cells cluster with and without overlapping shown. The offered traffic per interfered channel is assumed to be constant and equal to 0.4 Erlang, and a constant transmitter power $P_n = 33$ dBm [11].

The average propagation loss at any distance is given by [12];

$$ L(d) = 112.23 + 32.8 \log(\frac{d}{1000}) $$  \hspace{1cm} (1)

Under the considerations, omni directional antenna, $h_{ms} = 2$ m, $h_{bs} = 45$ m, transmitter frequency of 895 MHz and the distance $d$ in Km. Considering cell radius $R = 1000$ m and adaptive overlap distance to be 0.2*R [13], hence the minimum distance in case of no overlap $D = 2645.7$ m, and minimum distance in case of with overlap is $D_{ov} = D - 0.4*R$, and the radius became $R_{ov} = R + 0.2*R$. The minimum distance corresponding to the highest interference situation considered as the worst case which must be considered to evaluate the system performance accurately. The interference between two co-channel cells separated by distance $D$ without overlap will be:

$$ I(D) = P_n - L(D) $$

$$ I(D) = -93.09 \text{ dB} $$  \hspace{1cm} (2)

For the first tier interferes there are at maximum six active interferes and seven interference states (0-6). To calculate the total interference, the contribution of these interferes must be considered, hence the total interference become:

$$ I|_{at} = 10 \log 10 \sum_{n=1}^{6} P_n \cdot I_n |_{at} $$  \hspace{1cm} (3)

Where $I|_{at}$ is the total interference strength in dB caused by the first tier co-channel cells, $P_n$ is the probability of n active interferers from seven interference states (0-6) and can be obtained from the offered interfering traffic using the Erlang state distribution formula, hence the offered traffic per interfering channel equal to .4 Erlang, so that the total interfering traffic $A = 6 \times 0.4 = 2.4$ Erlang, then $P_n$ equal:

$$ P_n = \frac{A^n / n!}{\sum_{i=0}^{n} A^i / i!} $$  \hspace{1cm} (4)

$I_n |_{at}$ represents the interference power in watts for n active interferers, given in the table 1.

### Table 1: interference strength for n active interferes

| Active interferes | $I_n |_{at}$ | $I_n |_{ov}$ | comment |
|-------------------|------------|------------|----------|
| 0                 | $10^{-11.4}$ | $-116$     | Noise    |
| 1                 | $10^{-9.309}$ | $-93.09$   | Single interferer |
| 2                 | $10^{-9.085}$ | $-90.08$   | Double interferers |
| 3                 | $10^{-8.852}$ | $-88.32$   | Ternary interferers |
| 4                 | $10^{-8.370}$ | $-87.07$   | Quaternary interferers |
| 5                 | $10^{-8.911}$ | $-86.1$    | Quintuple interferers |
| 6                 | $10^{-8.533}$ | $-85.31$   | Sextuple interferers |

The total interference in dB in no overlap case will be:

$$ I|_{at} = -89.394 $$

Now to calculate the carrier strength, the average intra cell MS-BSS distance must be obtained because it influences the mean carrier strength. From [11], this distance can be approximated by the radius of a circle covering half of the hexagonal cell area, $R_{MS-BSS}$ given by:

$$ R_{MS-BSS} = \left( \frac{A_{Hex}}{2 \pi} \right) = \frac{1.5\sqrt{3}R^2}{2\pi} = 643 \text{ m} $$  \hspace{1cm} (5)

Hence the average carrier strength will be:

$$ C(R_{MS-BSS}) = P_ms - L(R_{MS-BSS}) $$

$$ C(R_{MS-BSS}) = 72.94 \text{ dB} $$  \hspace{1cm} (6)

The mean carrier to interference ratio $CIR_{mean}$ calculated from the following relation:

$$ CIR_{mean} = C(R_{MS-BSS}) - I|_{at} $$

$$ CIR_{mean} = 16.45 \text{ dB} $$  \hspace{1cm} (7)

To get the carrier to interference ratio in case of applying overlap $CIR_{mean-ov}$ by using the equations (1-7) considering the following numerical values, the cell radius became $R_{ov}$, the minimum distance between two co-channel cells became $D_{ov}$, then, the interference strength due to a single interferer, the total interference strength due to six interferes, the average intra MS-BSS distance, the average carrier strength and the mean carrier to interference ratio are shown in the following respectively, while overlapping assumed:

$$ I(D_{ov}) = -90.755 \text{ dB} $$

$$ I_{ov} = -87.057 $$

$$ R_{MS-BSSov} = \left( \frac{A_{Hex}}{2 \pi} \right) = \frac{1.5\sqrt{3}R_{ov}^2}{2\pi} = 771.64 \text{ m} $$

$$ C(R_{MS-BSSov}) = -75.537 \text{ dB} $$

$$ CIR_{meanov} = 11.52 \text{ dB} $$

As shown from the above results that the existence of overlapping reduce the carrier to interference ratio between co-channel cells by about 5dB, this reduction in CIR will control the choice of the coding scheme. The optimum choice of CS will compensate both the reduction in the CIR and the excess in Block Error Rate (BLER). In this work the lowest value of CIR ($CIR_{meanov}$) was considered, so that the simulated model operate at the worst case (not the ideal case). At this value of CIR the BLER is less than 0.2 with respect to CS3 curve, so that CS3 can be used as a coding scheme and there is no need to use a more protection coding scheme [14]. [10, 15] present the optimal choice of the coding scheme as a function of the CIR, if the value of CIR is known, then the coding scheme that maximizes the throughput can be chosen correctly. After determining the suitable coding scheme which will do well at the obtained value of CIR and with BLER lower than 0.2, so that in the proposed approach the use of CS3 as a coding scheme for GPRS traffic will compensate...
the leakage in CIR due to adaptive overlapping while maintaining lower BLER (<0.2) and maximize throughput. The use of overlapping adaptively mean that there is no permanent overlapping and it is applied under conditions, thus will affect the system greatly, hence the model is designed considering the lowest CIR ($CIR_{\text{mean}}$) while adaptive refer to that the CIR can change between lowest value ($CIR_{\text{mean}}$) and highest value ($CIR_{\text{mean}}$), thus will reduce the BLER by approximately 0.888. This reduction will allow the use of lowest degree of protection coding scheme (CS4), and thus will maximize the throughput.

IV. SIMULATION STRUCTURE

In this paper a simulator for GPRS at the radio link control level has been carried out and developed in Matlab environment, the simulator focuses on the communication over the radio interface between MS and BSS, because this is one of the most crucial aspects of GPRS operation. The simulation considers a two dimension GSM/GPRS network, in which the coverage area is partitioned into seven hexagonal cells. To allow for a finite number of cells to be simulated while still approximately an infinite system, a warp-around technique is used, this mean that opposite sides warp-around, so that the finite size effect is eliminated. The simulator describes the behavior of a single carrier eight time slots GSM/GPRS system in which one channel (time slot) is reserved for control signaling, another channel is reserved for GPRS data sessions, the remainder six channels are shared by both circuit switched GSM services and GPRS data sessions. The arrival of voice calls and data sessions are modeled according to two mutually independent poisson processes, both of them are scheduled to share the radio resources.

When a new data session arrives it will be served. If there is no available resources it will be stored in the access queue waiting for a finite time, during this time if resources are available it will be served, if not it will be cleared due to buffer time expiring. When a new voice call arrives it takes a free channel, if there is no channel available and the number of voice calls in the service is below six, hence one of GPRS data sessions stops its transmission in order to allocate a channel to the new voice calls. The interrupted data session stored in the suspend queue without limitation on the storing time. When resources are available again, the data sessions in the suspend queue have higher priority to be resources allocated than the new data session or data session in the access queue. The discipline in the access and suspend queue follow the first in first out (FIFO) principle which is the simplest scheduling and queuing method. The average service time of circuit switched calls and packet switched data sessions are assumed to be exponentially distributed with mean 120 and 20.382 seconds respectively. The voice traffic load is set to 2.275 Erlang to satisfy the general requirements of 2% blocking probability which is atypical target value for GSM operators, while the data traffic load range between 1 to 10 Erlang.

In this paper the Email traffic model is used, that has the following characteristics:

- Calls and data sessions arrived according to poisson processes.
- The coding scheme used is CS3, hence it is superior in the range of CIR between 10 and 17 dB [17].
- Single carrier, eight time slots.
- The length of the Email size is exponential distributed with a mean of 320 K bit [16].
- Average service time of 320000/15700 second.
- The data terminal can operate in MSC mode, up to seven time slots used simultaneously.
- The simulation is based on the assumption that all mobile stations use the same coding scheme.
- The mobile stations are assumed to be moving with a uniform truncated velocity between maximum value of 60 Km/h (vehicles) and minimum velocity of 5 Km/h (pedestrian).
- Access queue of length 20 and maximum storing time of 2 minutes.
- Suspend queue with infinite length and storing time.
- Cell radius set to be 1000 m.
- The queuing discipline is FIFO.
- Adaptive overlapping distance set to be 0.2 from cell radius.

As seen, the average service time of GPRS data session is not small, hence during the mobility of the data terminals, a hand off is required for these terminals, so that they can complete their data sessions. Without any schemes for handling hand off attempts, they will face high failure rate. Considering the proposed approach, if there are more than one hand off attempt in a cell, and they cannot find free resources in their new cells, hence their current serving base station will increase its power coverage by a fixed amount, so that they can be served by the old cell. During the moving of hand off users in the overlap region, one of the following events will take place:

- The data terminal finished its data transmission.
- The data terminal success to get a channel in the new cell.
- The overlap region finished and the data terminal is forced to terminate (hand off failure).

If there is no hand off attempts or there is a single attempt in a cell at a time, hence there is no overlapping region. The switching between the two cases depends only on the number of hand off attempts in a cell at a time. If a cell at any time provides overlapping region to serve their current users making hand off attempts, this region can serve data terminal in the access queue or a new coming data terminal , those users cannot find a free channel in the cell they are currently located, re-switching of these users is available to adjacent cell if all the following are true:

- The adjacent cell provides overlap.
- The GPRS user is in the overlapping region of the adjacent cell.
- The adjacent cell has free radio resources.

If one of the above conditions is false, the GPRS user will remain in the access queue or enter the access queue or blocked according to the user and system state.

V. SIMULATION RESULTS

The developed simulator was intensively utilized to investigate the behavior of the Email traffic model over GPRS. The simulation results show a strong enhancement in the GPRS operation. Figure (3) shows the main benefit of using overlapping between adjacent cells, because there is a greatly reduction in the hand off failure probability which represents main aspect in any wireless system. While figures (4,5) show that overlapping will affect the number of data sessions completed per second and the percentage of the
completed data sessions respectively. Figure (6) shows that overlapping will increase the percentage of RLC blocks served per second by the network, figure (7) introduces the throughput (channel utilization) improvement for GPRS data sessions. It is clear that overlapping enhances the operation of the GPRS system especially at high offered traffic load, but at lower and moderate traffic load there is lower enhancement. This is because, the adaptive overlapping can be approximated to be fixed overlapping at high traffic load. At this time the system operates at the worst value of CIR of its operation to accommodate the high traffic, while at lower and moderate traffic there is no need to work at the worst case and a larger value of CIR is sufficient to accommodate the given traffic load intensity.

The obtained results show the optimistic side of using overlapping. In fact the great reduction in the hand off failure probability was achieved on the cost of the increase in both the blocking probability of new data sessions and the RLC block delay as shown in figures (8,9) respectively. The re-switching approach is used here to alleviate the pessimistic effect of overlapping by increasing the chance of serving the queued and new data sessions. Figure (10) shows a tiny reduction in the blocking probability and this because the queued and new data sessions success to enter service by re-switching, the re-switched data sessions have a higher probability to be handed off, so that the hand off attempts will increase, but the hand off attempts have a higher priority than new attempts, therefore the blocking probability of new data sessions not reduced greatly. Re-switching also presents the following enhancements, there is a small reduction in the RLC block delay as indicated in figure (11), figures (12,13) show the increase in the percentage of the RLC blocks served per second the system throughput respectively.

VI. CONCLUSION

In this paper, it is clear that applying adaptive overlapping between adjacent cells in GPRS network using GSM channels improves the system performance. The contribution of this paper is fourfold. First, it’s clear that the overlapping between adjacent will enhance some of the crucial quality of service parameters especially at high traffic load intensity, for example, at offered traffic of 10 Erlang, the hand off failure probability reduced from 0.98 to 0.1612, also there is an enhancement in data terminal completed, served RLC blocks and throughput. Second, the existence of overlapping deteriorates the system performance by increasing the blocking probability of new data sessions and the RLC block delay. Third, the re-switching approach will minimize the above degradations slightly. Fourth, the net result of applying overlapping is optimistically, hence the benefit obtained overcome the detriment suffered.

REFERENCES

Figure (4): Effect of overlapping on the data sessions completed per second.

Figure (5): Effect of overlapping on the percentage of data sessions completed.

Figure (6): Effect of overlapping on the percentage of RLC blocks served.

Figure (7): Effect of overlapping on the throughput.

Figure (8): Effect of overlapping on the blocking probability of new data sessions.

Figure (9): Effect of overlapping on the RLC block delay.

Figure (10): Effect of re-switching on the blocking probability of new data sessions.

Figure (11): Effect of re-switching on the RLC block delay.

Figure (12): Effect of re-switching on the percentage of the RLC blocks served.

Figure (13): Effect of re-switching on the throughput.