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Improving EGPRS Capacity using Orthogonal Sub Channels (OSC)

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Abstract*— Due to the increasing demand for data services in mobile networks, operators are observing the quality of data services to degrade as their packed switched (PS) resources become insufficient. Even though there are newer 3/4G technologies available, EGPRS is still a good solution for data services due to ubiquitous coverage, the availability of low cost user terminals and its low deployment costs. Hence, alternative solutions are needed to deal with this increased data traffic without affecting the voice services, which play an important role in GSM networks. This paper presents a study on the usage of the Orthogonal Sub Channels (OSC) for improving voice capacity in order to increase the available resources for PS data services in a GSM/EGPRS network, showing that along with OSC it is possible to increase the number of EGPRS subscribers without extensive capital expenditure, such as increasing the number of radios or acquiring further spectrum resources.** ***Keywords*— *GERAN Evolution; EGPRS; OSC; Capacity.

I. INTRODUCTION

As smart phones become more common, the number of users using data services is expected to increase. Although new technologies like UMTS and LTE may be used to fulfill this demand, in certain situations, specially in developing markets, these technologies may be excessively expensive and have coverage limited only to hot spots. This increasing demand is pushing the existing EGPRS networks towards their limits, causing reduction in the throughput and increasing the data transmission delay. One alternative is to increase the voice services hardware efficiency with OSC to free resources in the existing infrastructure, increasing the number of slots available for data capacity in EGPRS networks, and avoiding high capital expenditure in such areas.

The new Orthogonal Sub Channels (OSC) concept [1] aims at increasing GSM voice capacity using the same number of channels. It introduces a new channel mode called Double Half Rate (DHR), which is capable of doubling Half Rate (HR) channel's capacity. This improved hardware efficiency turns it possible to reduce the number of circuit switched (CS) resources while maintaining the same voice capacity with similar quality [2].

Hence, many applications may arise from the use of OSC. The first one is to reduce the GSM frequency resources in order to accommodate 3/4G technologies, like HSPA or LTE, without further bandwidth licensing requirement [3]. In this case, spectrum of GSM services may be reduced while keeping the same voice capacity and quality, and saved spectrum can be used for 3/4G technology. The second application enables the usage of better codecs, viz. the wide band adaptive multi rate voice codec (AMR WB), by using robust channel modes enabled with OSC [4]. Additionally, in a distant future, GSM could in some cases be deployed with very low bandwidth as a roaming solution.

This paper presents another application, which would involve efficient use of resources to accommodate increased EGPRS traffic in the network. This situation could arise in networks with high number of GSM/EGPRS low end devices; in developing countries or rural areas where the costs associated with HSPA or LTE deployment would be to high; or in networks that will provide some new low cost services, as Machine Type Communications (MTC), which uses low data rate per subscriber, but may degrade the network performance due to the significantly high number of users [5]. Thus, OSC is an alternative solution even for the EGPRS services sharing the same bandwidth, since with its deployment it is possible to reduce time slots for CS traffic while increasing packed switched (PS) resources.

Therefore, this paper shows system level results with the performance of both voice and data services. The simulations shown in the paper provide results used to estimate the expected EGPRS capacity gains depending on the CS territory reduction. On the other hand, study also targets on the possible quality improvements, in terms of throughput and delay, when both CS and PS traffic are kept constant.

This paper is organized as follows: Section II presents the OSC concept discussed in 3GPP GERAN Technical Specification Group, while the simulation scenarios are explained in Section III, and the simulation results are shown in Section IV. Conclusions are provided in Section V.

II. OSC CONCEPTS

OSC is a feature proposed under Multi User Reusing One Slot (MUROS) in 3GPP GERAN Technical Specification Group (TSG) [6], and will be specified in Voice services over Adaptive Multi-user channels on One Slot (VAMOS) in 3GPP Release 9. It introduces new channel modes to GSM capable of conveying bursts from two users simultaneously using the same radio resources, thus increasing GSM hardware efficiency.

In downlink, when using OSC, the BTS multiplexes the data from both users by means of a QPSK signal that is generated using the existing 8PSK modulator of EGPRS radios, as in Figure 1. The data is modulated in such a way that the information for one user is in the most significant bit while the least significant one bears the data for the other user. There is no need for any change in mobile station's receiver since it will be able to decode the information from the in phase or quadrature parts of QPSK using low correlated tranning sequences as an ordinary GMSK signal. However, in most cases, a receiver which uses interference rejection techniques may be necessary in order to maintain the bit error rate under acceptable values.

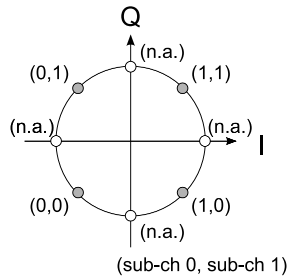

Fig. 1. 8PSK constellation symbols used on OSC.

On the other hand, in uplink, each mobile station will independently send its signal using GMSK modulation as usual. The diversity antenna receiver in the BTS will separate the signals by means of techniques such as Interference Rejection Combining (IRC), Successive Interference Cancellation (SIC) or Joint Detection (JD), and the knowledge of the trainning sequences.

Hence, the usage of OSC increases the capacity of Full Rate (FR) and Half Rate (HR) channel modes, creating new ones named Double Full Rate (DFR) and Double Half Rate (DHR) in which up to 2 or 4 users are supported per time slot, respectivelly. Thus, the most significant benefit of OSC is to double the maximum achivable hardware capacity, which may be used to increase the network's offered Erlang in more than 100% in certain cases.

III. Simulation Assumptions

A dynamic cellular network system level simulator [7] was used in the analysis of the proposed scenarios. In these simulations, logical connections and physical links between base stations and user equipments (UE) are modeled in detail. The regular urban macro cell network has 75 cells with an equal number of transceivers. The radio resource management (RRM) algorithms in BSC and PCU are also modeled according to specifications. UEs are uniformly distributed over the entire network area. A fixed number of slots was used in EGPRS territory pool for ease of comparison. However, some modifications in frame structure and RRM algorithms were necessary in order to support OSC connections.

The simulation scenario was chosen in order to check if the usage of OSC could improve EGPRS performance in a network. Details about the scenario are presented in Table I. Voice service was simulated using fixed AMR 5.9 codec, which provides a good compromise between voice quality and coding robustness. Channel mode was either AMR HR, or AMR HR and AMR DHR when OSC is enabled. In the second case, channel mode may be adapted in accordance to the radio conditions of each connection. Quality indicators for CS service used in the analysis were Blocked Call Rate (BCR) and Bad Quality Call (BQC), which is the ratio of users with BLER higher than 2%. Capacity estimation was made considering the maximum voice load, measured in Erlang per cell, in which BCR is lower than 2% and BQC is lower than 1%, 2% or 3%.

TABLE I
Simulation Scenario

Frequency Band	900 MHz
Cell Radius	500 m
Bandwidth	5.0 MHz
Guard Band	0.2 MHz
Number of TRX	4
BCCH Frequency Reuse	4/12
TCH Frequency Reuse	1/1
Frequency Hopping	Synthesized
Number of FH Frequencies	12
Fast Fading Type	Typical Urban
MS Speed	3 km/h
Network Sync Mode	Synchronous

The data service traffic was modeled using FTP in downlink with 100 kB files. No data service was used in uplink in order to reduce the simulation time. Results for evaluated data services show either the Net Throughput in kbit/s or the Net Delay in milliseconds versus the Offered Load in kbit/s per cell. Net Throughput and Net Delay are calculated, for each connection, in such a way that the time when there is no data to be transfered in the BS buffers is discarded. Offered Load is calculated considering the total data transfer requested by all subscribers.

Firstly, an initial case in which OSC was not enabled was used as a reference to evaluate the improvements achieved using OSC. Some simulations with different numbers of voice service subscribers were used in order to find the point in which the network reaches the 2% BCR limit or BCQ constraints. Then, the number of slots in the PS territory was increased from 7 to 15 and the number of PS subscribers was increased to check the impact on EGPRS capacity. For each new PS territory/subscribers point, the voice limiting point was obtained using new simulations. Using this information, it was possible to define the values for the data KPI at the limiting points.

After the first set of simulations, the same process was repeated for the second set in which OSC was enabled to evaluate the effect on the network, without any changes to the number of subscribers or the data service configurations. The capacity limiting factor in this case was the number of Bad Quality Calls.

IV. Simulation Results

Simulations were performed based on the assumptions described in III, for different number of PS time slots, while keeping the voice capacity at 36 Erlang/cell, and considering BCR lower than 2% and BQC lower than 1%, 2% and 3%. After this first step, PS territory is determined as the maximum number of time slots for which the CS capacity is kept under the minimum quality constraints. The number of time slots for HR channel case was 7 for any BQC criteria, while for DHR it was 9, 10 and 11 slots for BQC $<$ 1%, 2% and 3%, respectively.

Given the PS optimum territory for each CS channel mode and BQC target, the PS load is varied in order to evaluate its behavior. Hence, Figures 2, 3 and 4 show the mean and the 90th percentile of Net Throughput and the mean Net Delay for the HR case and for the DHR case considering BQC lower than 1%, 2% and 3%. Observing those figures it is possible to notice a big improvement in data KPIs as OSC is enabled in the network. Thus, two improvement paths for this network configuration may be suggested:

- Increase the throughput and reduce the delay while keeping the current PS capacity;
- Increase the data capacity of the network, measured in offered load, while maintaining the current service quality.

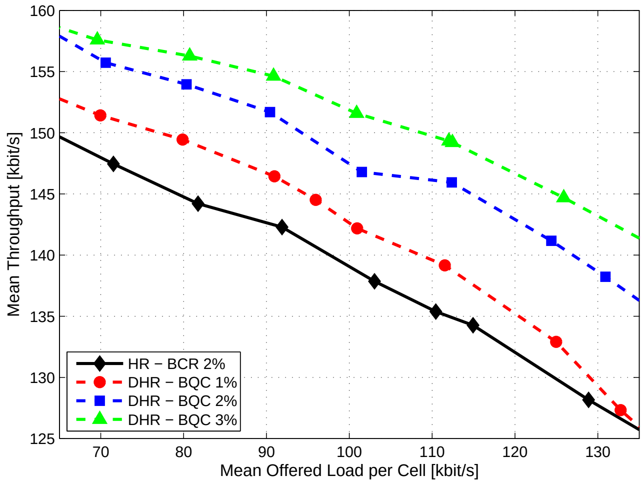

Fig. 2. Mean Net Throughput vs Offered Load.

Table II shows the approximate values of the data services KPIs taken from Figures 2, 3 and 4 for fixed voice and data capacity of 36 Erl/Cell and 80 kbit/s/Cell respectively. Those results show that data KPIs can be significantly improved by increasing the PS territory, hence considerable EGPRS service quality gains are achieved when OSC is enabled. 90th percentile Net Throughput results are doubled when BQC $<$ 3% criteria is used. 90th percentile of Net Throughput results show significant improvement, since it is be doubled if BQC $<$ 3% is used.

Table III shows another set of results, where data service quality already meets the operator requirements. In this case Offered Load (kbit/s/Cell) was determined for each simulation case, considering a Mean Net Throughput of 145 kbit/s, 90th Percentile of 41 kbit/s, and Mean Net Delay of 27 ms. This table shows that if only Mean throughput is considered, there can be an increase in data traffic of more than 56%, if BQC $<$ 3% is used as minimum voice

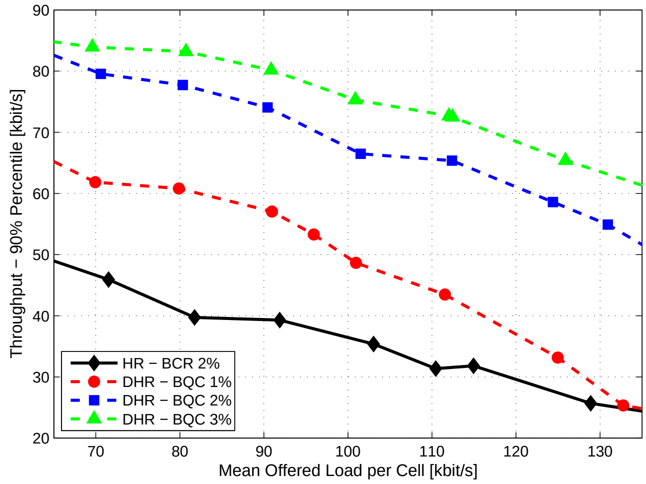

Fig. 3. Net Throughput (90th Percentile) vs Offered Load.

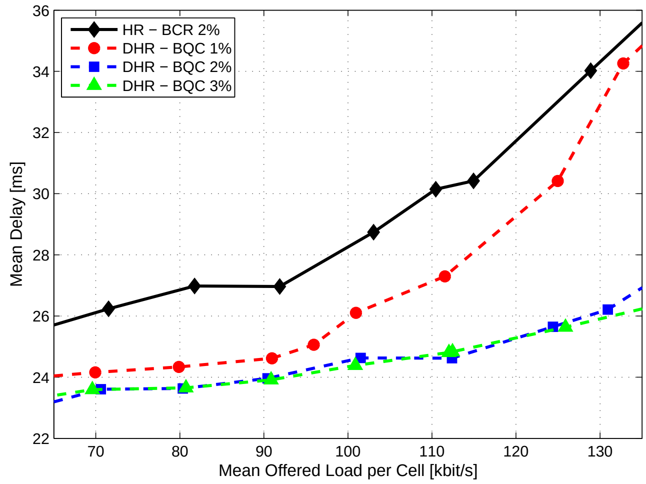

Fig. 4. Mean Net Delay vs Offered Load.

TABLE II
Simulation Results Constant Erlang (36 Erl/Cell) and Offered Load (80 kbit/s/Cell), KPI values and relative improvement of DHR over HR.

Simulation Case	**Mean Net Throughput**	**90th Percentile**	**Mean Net Delay**
HR - BCR 2%	145	41	27.0
DHR - BQC 1%	150	61	24.5
DHR - BQC 2%	154	77	22.5
DHR - BQC 3%	157	83	22.5
DHR - BQC 1%	3%	49%	-9%
DHR - BQC 2%	6%	88%	-17%
DHR - BQC 3%	8%	102%	-17%

quality. For 90th throughput percentile and Mean Net delay, the capacity gains are even higher than 70% if BQC $<$ 2%. According to results in Table III, it is possible to infer that if a network operator is willing to keep all PS KPIs at the same level, it would be possible to increase the number of users by up to 56%, depending on the desired voice quality.

TABLE III
PS CAPACITY FOR CONSTANT ERLANG (36 ERL/CELL) AND DATA SERVICE QUALITY, GIVEN IN OFFERED LOAD (KBIT/S/CELL) AND RELATIVE IMPROVEMENT OF DHR OVER HR.

Simulation Case	Mean Net Throughput [145 kbit/s]	90th Percentile [41 kbit/s]	Mean Net Delay [27 ms]
HR - BCR 2%	80	80	80
DHR - BQC 1%	94	115	109
DHR - BQC 2%	114	>135	135
DHR - BQC 3%	125	>135	>135
DHR - BQC 1%	18%	44%	36%
DHR - BQC 2%	43%	>69%	69%
DHR - BQC 3%	56%	>69%	>69%

V. CONCLUSION AND FUTURE WORK

GSM and GPRS/EGPRS are still under continuous evolution and standardization despite the availability of newer technologies such as HSPA and LTE. Their importance is high in developing countries, rural areas, and for areas with high concentration of low end mobile stations. Although the development is most of the time separate for CS and PS services in GERAN, any development in one service area may impact significantly and bring benefits for the other.

This paper has shown that voice evolution may bring interesting effects over data services. In this study, OSC feature proposed in GERAN was implemented in system simulations, and it was used to increase the number of resources dedicated for data services. Since OSC is meant for increasing hardware efficiency in GSM networks, by using this feature it is possible do decrease the number of time slots dedicated for voice, bringing benefits of PS users.

The results show that OSC may be used to increase the data service traffic in the network maintaining the quality of the service unaltered. It was shown that PS capacity can be improved up to 56%, depending on the requirements of quality over CS services. Furthermore, if only 90th throghput percentile or Net Delay are considered, PS capacity gains may be higher than 70%.

Additionally, it is also possible to improve the quality of the service while keeping the current PS traffic. In this paper, it is demonstrated that, when the hardware efficiency of voice services increases, resources are released, and these resources may be used to increase the throughput and to reduce the delay when the same data traffic is kept in the network.

Finally, this paper has shown that OSC deployment offers the network operator the possibility to adjust the territory size according to the evolution of the network. Hardware efficiency improvement brought by OSC makes it possible to an operator to plan a proper balance between desired capacity versus quality constraints. For future studies, it is suggested to verify the combined gains that may be obtained if the network uses OSC and EGPRS2 [8]. This can be used to estimate how these two new features working together may increase the capacity of a GSM network, and provide improved efficiency in resource usage, which can be used to accommodate increasing traffic, or to refarm GSM spectrum for newer technologies.

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