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Name:	Ralf Pabst, Peter Seidenberg
Affiliation:	Communication Networks Aachen University of Technology
Address:	Kopernikusstr. 16 D–52074 Aachen, Germany
Phone:	+49 241 88 90341
Fax.:	+49 241 80 22242
E-mail:	{pab|psg}@comnets.rwth-aachen.de

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Coexistence of UMTS and EGPRS to enhance network capacity

Ralf Pabst, Peter Seidenberg

Communication Networks
Aachen University of Technology
Kopernikusstr. 16
D–52074 Aachen, Germany
Phone: +49 241 88 90341
E-mail: {pab|psg}@comnets.rwth-aachen.de

Abstract

This paper investigates the spectral coexistence between UMTS and EDGE Mobile Radio Networks. The simultaneous operation of these two different 3rd Generation Radio Access technologies in the same frequency band and in the same area offers interesting perspectives regarding „soft“ migration scenarios from existing 2nd generation networks towards IMT-2000 compliant services. Specific features of the respective systems are modeled and a sample scenario is presented, focusing on a UTRA-FDD speech service and the packet-switched EGPRS-bearer. The analysis concentrates on QoS-parameters from a user's point of view, like the Bit Error Ratio (BER) for speech connections and Per-user-throughput for the packet switched service. Furthermore, it is shown that an overlayed UMTS/EDGE network can have a higher spectral efficiency than one single UMTS or EDGE network. Finally, a recommendation on boundary conditions which allow the coexistence of the aforementioned systems is given and a system-spanning control of services, traffic load and thus of interference which could be managed by an „Integrated Radio Resource Management“ for both systems is suggested. In this context, a particularly important issue would be the application of a combined Power Control mechanism in both networks and its positive influence on the mutual interference between both systems

1 Introduction

This paragraph will give a brief overview about the different possibilities of combining UMTS and EDGE in the space-, frequency- and time-domain.

Due to the advantages of EDGE in rural environments (larger possible macro-cell sizes than UMTS, high data rates for a limited number of users) and the strengths of UMTS in high-traffic scenarios like urban centers, trade fairgrounds etc., the most probable situation will be the regional coexistence between the two systems, both belonging to the same operator and thus operating in the same frequency band. This allows the operator to benefit from already existing sites and infrastructure in rural areas while being able to to roll out the UTRA services gradually without lacking coverage (the existence of multimode terminals assumed).

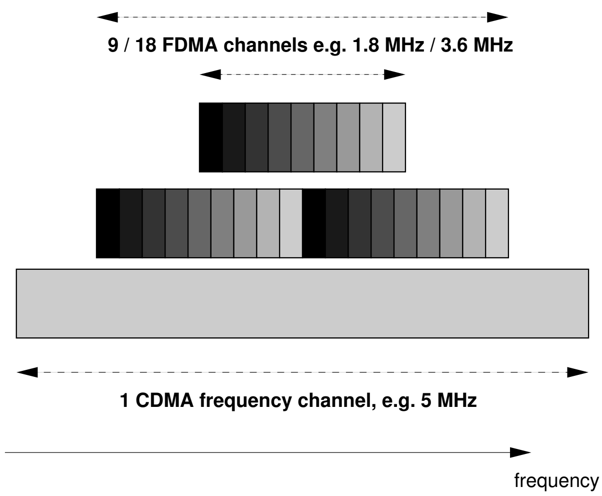


Figure 1: Frequency Allocation

In the aforementioned case interaction between the two systems can be estimated to be rather low, since the areas where both of them locally coexist (the system borders) are relatively small compared to the total coverage areas. This investigation therefore focuses on the case of 100 % overlapping cell areas and 100 % overlapping frequency bands (compare [4]). The possible applications are wide-spread. One example would be a network operator with an existing EDGE (or GSM)-network starting to offer high-rate UMTS-services, while still using the EDGE network for services like speech or low-bandwidth data. This would afford complete coverage for EDGE-services and therefore mean local coexistence. Since sites are rare and expensive resources of the network operators, it will be most likely that co-sited antennas for EDGE and UMTS would be applied in that case. A sample scenario depicting this case is displayed in figure 4.

2 Mutual Interference

The two main reasons for the advantageous interference situation between the W-CDMA system UMTS and the narrow-band EDGE network are the different bandwidths of the carriers and the spreading. The narrowband receiver filters of the EDGE system select a very small amount of the total wideband interference power originating in UMTS.

Since the allocated spectrum of EDGE is locally distributed over the whole area of 1 cluster, every UMTS-receiver is only interfered in a small fraction of the EDGE-spectrum and this interference is of narrow-band nature (see figure 1). The de-spreading at the UMTS-receiver helps to reduce the spectral power density of the narrowband interference signals as shown in figure 2. Another positive aspect is the interference diversity typical for a packet-service like EGPRS. It helps to keep the duration of very harmful interference situations (small coupling loss between interferer and victim) short. In the case of circuit-switched operation in EDGE (Voice, ECSD) the interference diversity could be achieved by a frequency hopping scheme (FH).

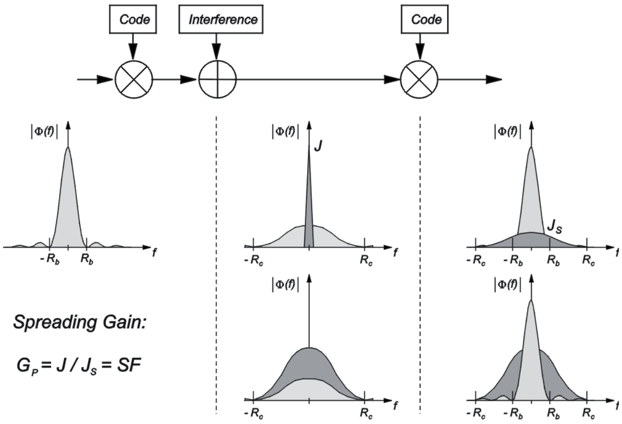


Figure 2: Spreading of narrowband interferers

Table 1: UTRA fix and variable parameters

Fixed Parameter	Value
Carrier Frequency	UL:1922.5 MHz, DL:2112.5 MHz
Carrier Spacing	5 MHz
Cluster Size	1
Cell Radius	1000 m (Macro)
BS Dynamic Range	0 dBm – 43 dBm
MS Dynamic Range	-50 dBm – 24 dBm
Receiver Noise	-100 dBm
Power Control	C/I-based, see [2]
DTX	None
Receiver Filter	Root-raised Cosine (roll-off=0.22)
DL Orthogonality	30 %
BS Antenna	Omnidirectional (Gain = 0 dBi)
Service Type	Speech
Bitrate	12.2 kbps
Spreading Factor	64 (UL) and 128 (DL)
C/I-target	-18.25 dB for UL and DL

variable Parameter	Range
Speech Traffic	5 Erlang . . . 50 Erlang

3 System Aspects

This section briefly describes how the most important system aspects are modeled in the event-driven simulation environment.

UTRA-FDD In UTRA-FDD, a 12.2 kbit/s speech service is regarded. To evaluate the achieved Quality of Service (QoS), the remaining Bit Error Rate (BER) after the channel decoder was analytically estimated from the measured carrier to Interference ratio (C/I). The DL Orthogonality value of 30 % which can be found in table 1 means that only 30 % of the DL power originating in his own cell are received as interference by the victim MS.

EDGE For the EGPRS-system, a Link Adaptation(LA)-mechanism was implemented following the proposals of [3]. Incremental Redundancy (IR) was not regarded. Since the simulations performed here focus on the system-level, an ideal channel is assumed after the LA has taken place. An ideal channel in this case means that the gross throughput provided by the selected Modulation and Coding Scheme (MCS) is always achieved after the selection of the MCS most suitable for the

Table 2: EDGE parameters

Parameter	Value
Carrier Spacing	200 kHz
Cluster Size	9
BS Dynamic Range	0 dBm – 40 dBm
MS Dynamic Range	0 dBm – 33 dBm
MS/BS Multislot Class	2
Receiver Noise	-114 dBm
Power Control	C/I-based
Receiver Filter	ideal rectangular
BS Antenna	Omnidirectional (Gain = 0 dBi)

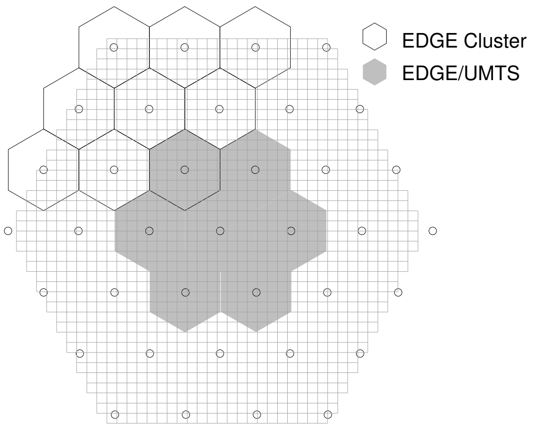


Figure 4: Simulation Scenario consisting of 7 combined UMTS/EDGE-cells (gray) and 37 EDGE-cells in total. Cluster sizes are 9 for EDGE, 1 for UTRA-FDD)

current radio conditions has been performed. The throughput values are measured at the top of the RLC-Layer and therefore must not be mistaken for user data throughput.

Packet scheduling is done statistically. At regular intervals all resources of a BS are freed and reallocated again. Then the reallocation algorithm randomly picks MSs from the queue of waiting stations and assigns them a channel until all resources of the BS are allocated.

This scheduling strategy is sufficient to model the interference diversity in a packet-switched network.

The EDGE-system was operated under application of a fast (20 ms-cycle) Power Control algorithm which allowed to moderate the impacts of the near-far-effect on the coexisting UTRA-FDD-system.

The packet sessions were generated following the HTTP-traffic model described in table 3

4 Simulation Scenario

To investigate the scenario described in section 1, a hexagonal cell scheme was chosen (see figure 4)

Table 3: HTTP session according to [1]

Parameter	Distribution	Mean
Number of Packets	Geometric	5
Packet Size	Geometric	12 kB
Reading Time between Packets	Geometric	12 s

Due to the cluster size of 9 in EDGE, 37 cells are required to yield a realistic interference floor while 7 UMTS-cells were considered sufficient to produce the necessary noise at the innermost station, which was used for the evaluation exclusively as already described in [2]. The partly missing back coupling generated in both systems by a lacking outer ring of 12 additional UMTS-BSs was modeled by an increased default UL noise rise of approx. 2 dB in the outer ring of 6 UMTS-cells.

The propagation model was taken from [1]. The topology is considered to be flat rural without buildings, so that all connections are LOS. Multipath Fading and Shadowing were not regarded in order to work out the effect of inter-system interference more clearly.

To faciliate the interference calculation between asynchronous systems, the EGPRS-system was always regarded at 100 % channel utilization. Different amounts of traffic and thus varying interference originating from EDGE were modeled by varying the number of EDGE-Transceivers(TRX) on the cells between 1 and 2.

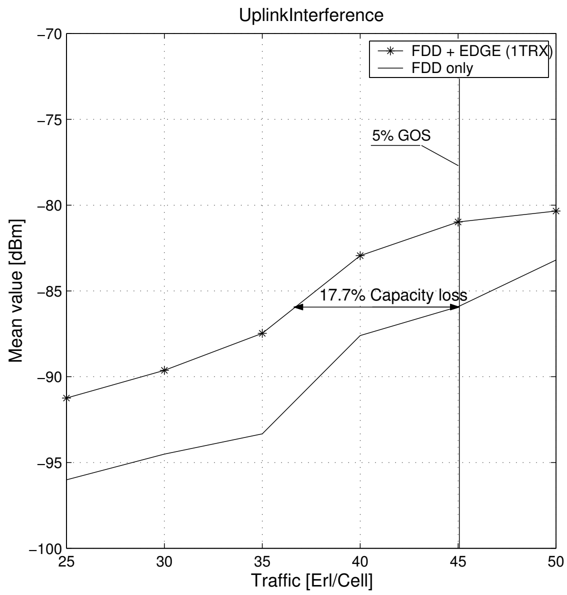
5 Results

The simulation results show that under certain boundary conditions, a coexistence between the two systems is possible:

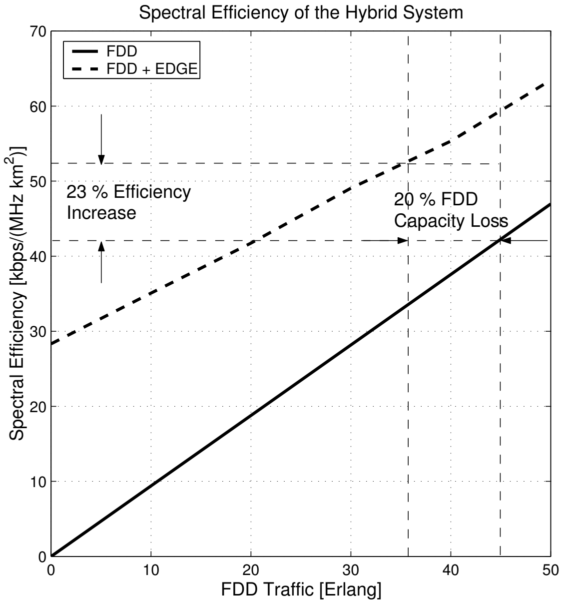
Firstly, it showed that the operation of 2 EDGE-channels (18 in total) per UMTS-cell produced too much interference to still allow for proper functioning of the FDD-system. The evaluation therefore concentrates on 1 EDGE-channel per cell (7 PDCHs+1BCCH). This channel is allocated in the center of the UMTS-spectrum as depicted in figure 1, leaving open the possibility of shifting the EDGE-carriers to the borders of the allocated spectrum where crosstalk can be expexted to be smaller.

Secondly, it is recommended to use high spreading factors in UTRA to benefit from the high processing gain. (to allow for lower C/I). The use of even lower spreading factors (e.g. an 8 kbit/s speech-service) could further improve the interference situation and would lead to better UMTS-coverage while at the same time reducing the impact on the EDGE-system.

It is also very obvious that the use of a Power-Control (PC)-mechanism in the EDGE-system is inevitable to reduce inter-system interference and espe-



(a) UTRA-FDD: Mean Uplink Interference



(b) FDD and combined Spectral Efficiency

Figure 3: Simulation Results (1)

cially the near-far effect, which still is a serious issue because of the relatively limited dynamic range of the EDGE-Transmitters. The PC-mechanism used in EDGE in the course of this investigation was not very sophisticated. Further improvement is needed in the field of initial transmission power determination, as can be seen in figure 5(a): In the case of low UMTS-load and therefore low interference floor, the start/end of a single EDGE-transmission has bigger effect on the overall interference and the UMTS-PC needs longer to adapt to the new situation. This results in the larger percentage of high BERs for the 10-Erlang coexistence case compared to the cases with higher load.

The capacity decrease in the UTRA-FDD system can be derived from figure 3(a). The mean interference and the GOS from the reference case (GOS $< 5\,\%$,45 Erlang) is already reached at $\approx 80\,\%$ of the original traffic (GOS $< 5\,\%$, 37 Erlang) when EDGE without PC coexists.

Table 5 shows the capacity decrease in the EGPRS-system. Since the PDCH-utilization is 100 % at all times, the system performance depends on both the number of simultaneous sessions and the throughput per session. The higher the throughput, the higher is the average traffic offer each session generates. The EDGE-system suffers a capacity loss of approximately 25 % as the FDD-load increases from 0 to 35 Erlang.

A problematic Issue is the increasing UE power consumption. Due to higher uplink interference, especially the EDGE terminals will have to transmit at much greater power levels than in the uninterfered case (see figure 5(b)).

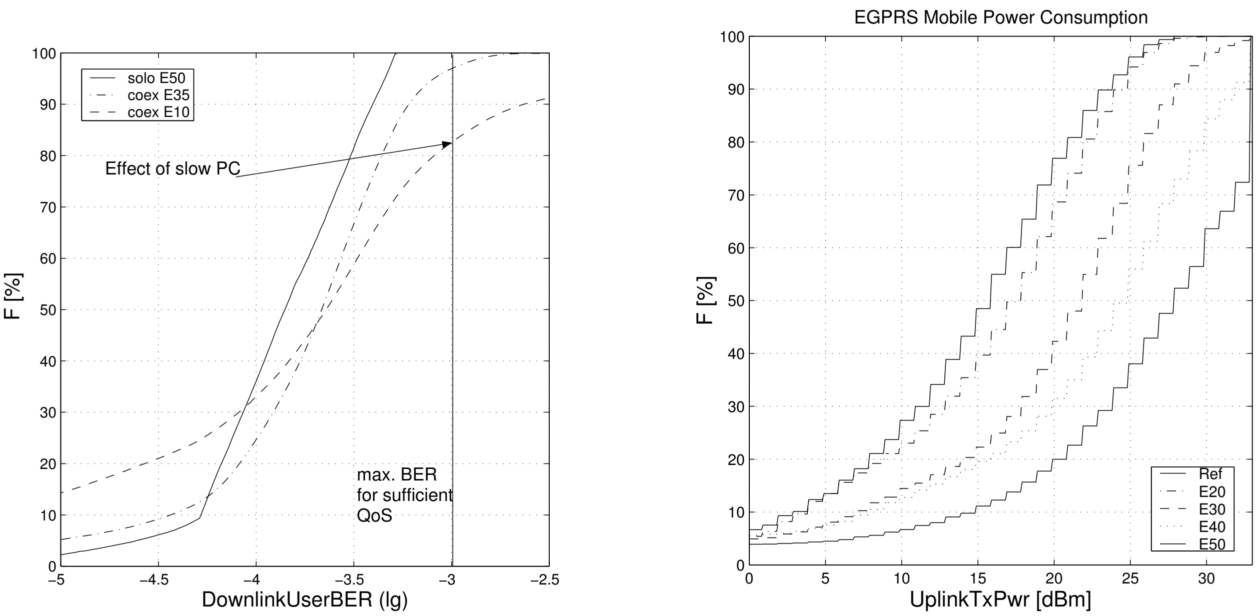
An interesting outlook could be the minimization of mutual interference by shifting the EDGE carriers from the middle of the UMTS-band (where they were located in this investigation, see figure 1) to its sides, where the crosstalk attenuation would be higher.

Table 4: UMTS spectral efficiency for 12.2 $^{\mathrm{kbit}}/_{\mathrm{s}}$ speech service

Traffic [Erl.]	Cell Throughp. $[^{kbit}/_{s}]$	Spectr. Eff. $\left[\frac{\mathrm{kbit/s}}{\mathrm{MHz\cdot km^2}}\right]$
10	122	9.3916
20	244	18.7831
30	366	28.1747
40	488	37.5663
50	610	46.9578

Table 5: Resulting EDGE Spectr. Eff. (1TRX)

FDD Traffic [Erl.]	TP per User $[^{kbit}/_{s}]$	mean Offer $[^{kbit}/_{s}]$	MS per cell	Cell TP $[^{kbit}/_{s}]$	Spectr. Eff. $\left[\frac{\mathrm{kbit/s}}{\mathrm{MHz\cdot km^2}}\right]$
0	39.8	7.991	46	368	28.33
10	38.7	7.940	42	333	25.69
20	36.5	7.849	38	298	22.96
30	34.5	7.753	35	271	20.89
40	33.3	7.691	30	231	17.76
50	32.7	7.658	28	214	16.50



(a) UTRA DL User BER

(b) EGPRS UE TxPwr

Figure 5: Simulation Results (2)

6 Conclusion

Under application of Power-Control in EDGE and high spreading factors in UMTS, the in-band-coexistence of both systems proves to be feasible. The capacity decreases in each system can be estimated to be smaller than 30 % even though a worst-case scenario was regarded here. To benefit from the above, a hybrid system should preferably transmit the low-bandwidth voice services via UMTS and higher rate packet data via EGPRS. It also proves that a combined system can have a higher Spectral Efficiency than one single UMTS or EDGE system as already suggested by [5] and [6]. If this option is seriously considered, it calls for a system-spanning control of services, traffic load and thus of interference which could be managed by an „Integrated Radio Resource Management“ for both systems.

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