Dynamic Half-Rate Allocation for Adaptive Multi-Rate Speech Codecs in GERAN Radio Networks

R. Müllner, C.F. Ball, K. Ivanov, H. Winkler, R. Perl and K. Kremnitzer
Siemens AG, Communications Mobile Networks
Munich, Germany / Vienna, Austria
robert.muellner@siemens.com

Abstract — **Capacity increase by utilizing half-rate speech codecs becomes very popular with the introduction of AMR. A most flexible solution is provided by switching dynamically between full-rate and half-rate codecs triggered by a combination of radio conditions and traffic load. The mobile network is optimized for highest speech quality and in parallel capacity will be provided wherever and whenever required. A detailed performance study of the AMR half-rate codec in GERAN networks has been performed based on system level simulations. The investigations focus on the trade-off between quality and capacity applying different frequency re-use pattern. The results show that a significant capacity gain can be achieved in networks with relaxed 4x3 and 3x3 frequency re-use planning. Even in tight 1x1 re-use networks AMR half-rate is applicable resulting in an additional capacity increase by switching calls in the inner area of the cell to half-rate. The proposed dynamic half-rate assignment strategy offers outstanding performance at competitive capacity. The cell capacity can nearly be doubled in 4x3 and 3x3 re-use networks at quality degradation lower than 0.5 MOS. In 1x1 re-use networks a capacity increase up to the soft blocking limit has been obtained.**

Keywords – Adaptive Multi-Rate Speech Codecs; AMR; AMR-NB; GSM; Quality of Service; coverage; capacity; performance

I. INTRODUCTION

For increasing voice capacity in GSM networks a handover functionality between full-rate and half-rate speech codecs has been introduced. The market penetration with the GSM half-rate codec in early deployment was only partly successful due to its minor reputation in terms of speech quality. With the introduction of AMR [1], however, the speech quality of half-rate codecs has been significantly improved compared to conventional GSM [2], [3]. Hence the utilization of half-rate becomes very attractive. Mobiles under good radio conditions can be forced by the network to change from full-rate (FR) to half-rate (HR) by compression handover. As a result radio resources are saved by multiplexing two voice calls in half-rate mode on a single GSM air interface time slot. If the radio conditions substantially degrade, a change back to the more robust full-rate mode will be automatically triggered (de-compression handover). Both compression and decompression handover are pure intra-cell handovers.

In this paper, the performance of AMR narrowband (AMR-NB) speech codecs in half-rate mode using GMSK modulation is studied in detail based on network planning studies as well as system level simulations. A novel dynamic half-rate allocation strategy is introduced taking into account radio conditions, system load and capacity requirements. Results on coverage, capacity, speech quality and codec mode distribution derived for typical frequency re-use planning ranging from relaxed 4x3 to tight 1x1 are presented. The paper is structured as follows: Section II introduces the proposed dynamic half-rate allocation strategy. An overview of the system level simulation model is provided in Section III. The simulation results on quality and capacity are discussed in Section IV. Finally the main conclusions are given in Section V.

II. DYNAMIC HALF-RATE ALLOCATION STRATEGY

The assignment of half-rate channels leads to a reduction of interference generated in the network and to a lower number of occupied resources. Two half-rate calls use one air interface time slot. Unpaired channels are avoided by enhanced pairing. Thus less hardware is required for serving the same number of users. The free physical resources can be used to serve additional subscribers and/or to increase the bandwidth for GPRS/EDGE data applications. This capacity gain, however, is not for free. Half-rate speech codecs provide a slightly lower perceived speech quality compared to that achievable on full-rate channels [2]. This is related to both speech coding and channel coding aspects. The maximum source bit rate on a half-rate channel using AMR-NB in GMSK modulation is considerably lower than for AMR full-rate speech (12.2 kbps). Taking into account a most economic utilization of the terrestrial A_{bis}/A_{sub} resources (8 kbps TRAU frames), the source bit rate in half-rate mode is even limited to 7.40 kbps. Due to less channel coding the AMR half-rate codec modes show less robustness against channel errors than AMR full-rate codec modes. Approximately 6 dB higher C/I is required to achieve a similar frame erasure rate (FER) performance. Consequently, half-rate codec modes are not suitable under bad radio conditions, e.g. at the cell border or in case of high interference. For connections under good radio conditions, e.g. in the vicinity of the base station, the AMR half-rate codec can be used to increase the capacity of the network while at the same time the perceived speech quality is kept at a satisfactory level.

A. Triggering of half-rate assignment by the combination of radio conditions and traffic load

The assignment of half-rate channels is linked to radio conditions and cell traffic load. Full-rate channels are allocated if sufficient radio resources are available thus offering highest quality whenever possible. Once the cell traffic exceeds a specific threshold, additional cell capacity is provided by switching from full-rate to half-rate. This compression handover is triggered for particular calls having good radio conditions in terms of C/I. The thresholds for initiation of full-rate/half-rate compression are settable and defined by the operator. If the radio conditions of a particular call fall below a specific threshold a switch back from half-rate to full-rate is triggered. This decompression handover is executed independently of cell load, i.e. a full-rate channel is allocated if at least one free time slot is available. In addition, cell load dependent decompression handover is executed in case of relaxing traffic load below a certain threshold.

B. Codec mode adaptation

After handover to half-rate mode, the AMR call starts in the initial codec mode e.g. the robust TCH/AHS5.15. Fast codec mode adaptation (CMA) switches to the best suited codec mode according to the prevailing radio link quality. In full-rate mode the call starts in the initial codec mode e.g. TCH/AFS5.9 and the codec mode adaptation algorithm chooses the proper codec mode. The AMR codec mode adaptation process is very fast and can be executed up to ten times per second.

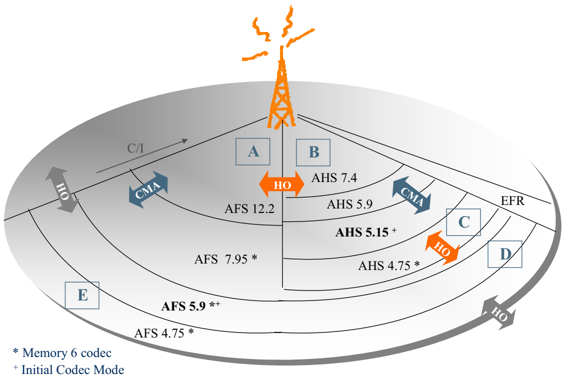

Fig. 1. Maximum flexibility by dynamic AMR-FR/HR mix – automatically triggered by radio conditions and traffic load

Fig. 1 presents an example for codec mode adaptation and compression/decompression handover. At call set-up the subscriber is located at position A and a full-rate channel is allocated. If the radio conditions are better than a given threshold (e.g. 15 dB) this particular call can be switched to half-rate mode. Compression handover is executed if the relative cell load is higher than e.g. 50%. After intra-cell handover to half-rate mode (position B) the initial codec mode is applied followed by the selection of the best suited codec mode according to the prevailing radio link quality. The subscriber moves now towards the cell border. Codec mode adaptation is continuously performed. Once the radio conditions fall below a specific threshold (e.g. 10 dB) a switch from half-rate back to full-rate is triggered (see the transition from position C to D). In full-rate mode the call uses the initial codec mode and the codec mode adaptation algorithm subsequently chooses the most proper codec mode. During the movement from position D via E back to A in full-rate mode the best suited codec mode is permanently adapted. Codec mode adaptation is executed not only at the border between two areas but also within each area due to fading effects. The coverage for the AMR codec modes is shown in Fig. 2 for different frequency re-use.

C. Interaction between (de-)compression handover and power control algorithm

Radio frequency (RF) power control (PC) is applied to minimize the transmit power to a level required just ensuring adequate speech/data quality over the radio path. PC leads to a reduction of the interference experienced by co-channel users and less power consumption of the transmitter. Control for compression/decompression handover operates simultaneously with power control, which also monitors quality and C/I trying to keep it within a fixed operation window. The objectives of power control and compression/decompression handover thus are in conflict: power control keeps the quality within the prescribed range, compression/decompression handover needs C/I as an unbiased measure of the channel. This aspect has been considered by appropriate interaction between compression/decompression handover and the power control algorithm.

III. SYSTEM LEVEL SIMULATION MODEL

The performance and capacity analysis of AMR-NB half-rate in GMSK modulation has been evaluated by a system level simulation model. The codec mode combinations (Active Codec Sets) shown in Fig. 1 have been selected for network planning studies and system level simulations. These Active Codec Sets include all available Memory 6 codecs for AMR-NB half-rate using GMSK modulation. Memory 6 codecs require a higher computational effort in the decoding process and outperform Memory 4 codecs in the obtained speech quality. A hexagonal cell layout in an urban deployment scenario for slow moving subscribers has been assumed. Voice traffic is exclusively allocated on hopping TCH TRX, i.e. the BCCH-carrier TRX is not considered. Table I gives an overview of the essential parameter settings.

Table I. Essential parameters of the system level simulation model.

Parameter	Value
Number of sites	61 (183 cells)
Site-to-site distance	900 m
TRX per cell (TCH TRX)	4 in (4x3, 3x3); up to 12 in (1x1)
Re-use pattern	4x3, 3x3 and 1x1
Frequencies per cell	4 in (4x3, 3x3); 12 in (1x1)
Path loss slope	37.6 dB per decade
Handover margin	3 dB
Adjacent channel suppression	18 dB
Fast fading profile	TU 3 (slow moving subscribers at a speed of 3 km/h)
Power control	level and quality based
Slow fading standard deviation	6 dB
Correlation distance	50 m
Voice codec types	AMR-NB FR GMSK (TCH/AFS), AMR-NB HR GMSK (TCH/AHS), EFR, GSM-FR, GSM-HR
Mean call duration	90 s
Voice activity factor (DTX)	0.6

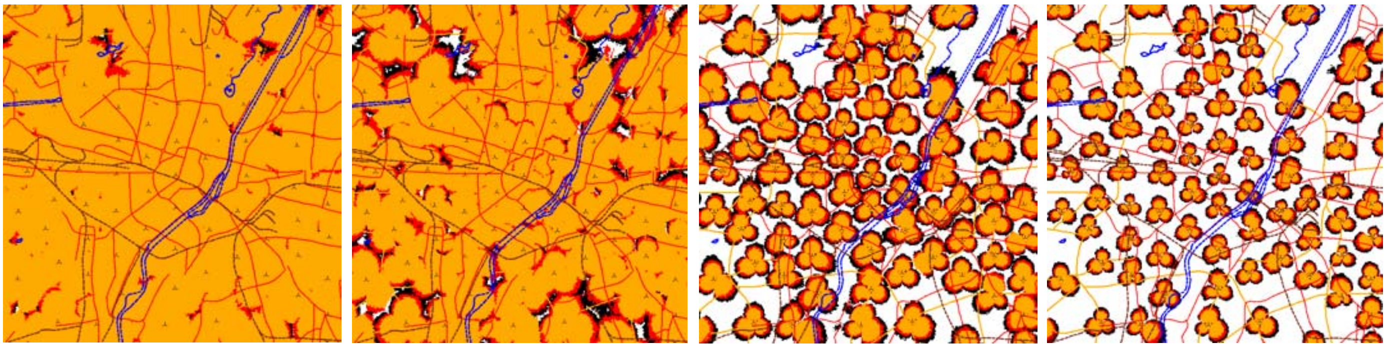

Fig. 2. Quality plots for AMR half-rate (TCH/AHS) from left to right: (a) re-use 4x3, (b) re-use 3x3, (c) re-use 1x3 and (d) re-use 1x1. Colors: orange (C/I ≥ 15 dB), red (12 dB ≤ C/I < 15 dB), black (9 dB ≤ C/I < 12 dB), white (C/I < 9 dB).

For re-use 4x3 and 3x3 an available frequency spectrum of 12 MHz and 10 MHz, respectively, is assumed including BCCH. The voice traffic on the four hopping TRX has been fixed at the hard blocking limit (22 Erlang @ 1% GOS). The tight re-use scenario 1x1 focuses on network operators with limited frequency spectrum of e.g. 5 MHz. A bandwidth of twelve hopping frequencies per cell has been assumed for TCH planning in re-use 1x1. Four TRX can be installed per cell in case of static MAIO allocation. Applying dynamic MAIO allocation in re-use 1x1, up to twelve TRX can be deployed depending on operator's capacity requirements. Thus installing sufficient number of TRX per cell, hard blocking due to lack of resources can be minimized. The performance of AMR half-rate codec modes has been evaluated in different traffic load scenarios. Real codec mode adaptation has been implemented. Latency in the link adaptation as well as in the power control algorithm has been modeled accurately. Capacity limitations resulting from decoding errors of FACCH/SACCH signaling channels and in-band signaling have not been considered. Advanced features like TX diversity, switched beams (adaptive antennae) and interference cancellation algorithms like SAIC [4] have not been taken into account. The focus of this study has been set to downlink (DL) simulations.

IV. SIMULATION RESULTS

A. Network planning study

A network planning study has been performed for dense urban and sub-urban deployment areas in Munich, Germany. The goal of the study was to evaluate the potential half-rate utilization in different frequency re-use patterns. Fig. 2 shows the worst case local mean downlink C/I for re-use 4x3, 3x3, 1x3 and 1x1 mapped on the operating ranges of the AMR half-rate codec modes TCH/AHS 7.40, 5.90, 5.15 and 4.75 kbps. Areas with a mean C/I exceeding 15 dB (orange color) indicate the typical operating range of the highest TCH/AHS7.40 codec mode. Red color marks a mean C/I between 15 dB and 12 dB, where codec mode TCH/AHS5.90 can be used. Areas with a mean C/I ranging from 9 dB to 12 dB are colored in black, corresponding to the assumed operating range of TCH/AHS5.15. White color indicates an area of mean C/I lower than 9 dB. The instant C/I fluctuates around the mean C/I value due to slow and fast fading. Hence real codec mode adaptation is also applied within areas of the same color and not only in the border regions of different color. The network coverage at 100% channel utilization in case of pure AMR half-rate allocation is summarized in Table II.

Fig. 2 shows that the mean C/I is substantially high for networks planned in relaxed frequency re-use 4x3 and 3x3. Codec modes of high source bit rate can be applied in almost the entire network. In tight 1x3 and 1x1 re-use networks half-rate codec modes of high source bit rate can only be applied in areas close to the base station. At the cell border, the C/I is typically too low for providing sufficient quality.

Table II. Network coverage using AMR half-rate allocation.

mean C/I	TCH/AHS	4x3	3x3	1x3	1x1
C/I ≥ 15 dB	7.40	97.1%	83.4%	34.6%	18.4%
12 dB ≤ C/I < 15 dB	5.90	1.4%	9.9%	13.5%	8.8%
9 dB ≤ C/I < 12 dB	5.15	1.5%	4.9%	16.0%	11.5%
C/I < 9 dB	4.75	0.0%	1.8%	35.9%	61.3%

In frequency re-use 4x3 networks even at full traffic load, the mean C/I is equal to or higher than 12 dB for 98.5% of the network area, while in re-use 3x3 this applies for 93.3% of the network area. In these scenarios the quality of service for voice calls is mainly characterized by the call blocking probability, defined by the percentage of blocked calls due to lack of physical resources. This is referred to as hard blocking.

B. AMR full-rate/half-rate performance in re-use 4x3

The performance and the number of utilized channels have been evaluated for different scenarios by system level simulations. The maximum offered load related to hard blocking is 22 Erl for 32 TCH corresponding to 1% blocking probability per 4 TRX cell. Voice calls are generated according to a Poisson process with arrival rate $\lambda_{voice} = 0.25$ and a mean call duration of 90 s. Only full-rate channels are assigned in the AMR-FR scenario. In scenario I for dynamic half-rate allocation (AMR-dynHR I) this arrival rate has been maintained and half-rate allocation has been enabled. The compression/decompression handover thresholds have been set to 15 dB and 10 dB, respectively. The assignment of half-rate channels is executed for a traffic load exceeding 50% of the cell capacity, i.e. if more than 16 time slots are occupied. Decompression handover due to relaxing traffic load is triggered if the current traffic load falls below 30% of the available resources (less than ten time slots in use). In scenario II (AMR-dynHR II) the offered load has been increased by

50% to 33 Erl. Scenario III is based on doubling the offered load from 22 Erl to 44 Erl. In scenario III, the thresholds for load dependent half-rate and full-rate assignment have been set to 30% and 10%. The essential scenario parameterization as well as simulation results have been summarized in Table III.

Table III. Traffic load and channel utilization for re-use 4x3 scenarios.

Scenario	AMR-FR	AMR-dyn HR I	AMR-dyn HR II	AMR-dyn HR III
Offered traffic load [Erl]	22	22	33	44
Cell load threshold for compression handover [%]	50	50	50	30
Cell load threshold for de-compression handover [%]	30	30	30	10
Observed hard blocking [%]	1.0	0.0	0.0	1.7
Mean num. of busy channels	21.6	14.4	18.2	24.0
Mean number of vacant TS	10.4	17.6	13.8	8.0

In the dynamic half-rate scenario I the number of vacant time slots has been increased by 69% compared to the pure full-rate scenario. No hard blocking has been observed, whereas a 1% call blocking rate has been reached by the pure AMR full-rate scenario. In the second dynamic half-rate scenario (AMR-dynHR II) the mean number of vacant resources has been increased by 33% compared to the pure full-rate scenario. The third dynamic half-rate scenario (AMR-dynHR III) leads to a reduction of the mean number of vacant time slots by 23% compared to the pure full-rate scenario. It is important to note that in all three half-rate scenarios a substantial number of calls is still maintained in full-rate mode. Typically mobiles at the cell border are kept in full-rate mode, while connections in the inner area of the cell are selected for half-rate operation.

The high capacity gain by half-rate allocation of nearly a factor of two has some impact on perceived speech quality. Fig. 3 shows the cumulative distribution function (CDF) for the mean FER per voice call in re-use 4x3 for the different traffic load scenarios. The statistics for each call include full-rate as well as half-rate phases. Requiring a mean FER < 1% the 4x3 re-use results in more than 98.8% coverage for all scenarios. The numerical values for mean FER lower than 1% and 2% are summarized in Table IV.

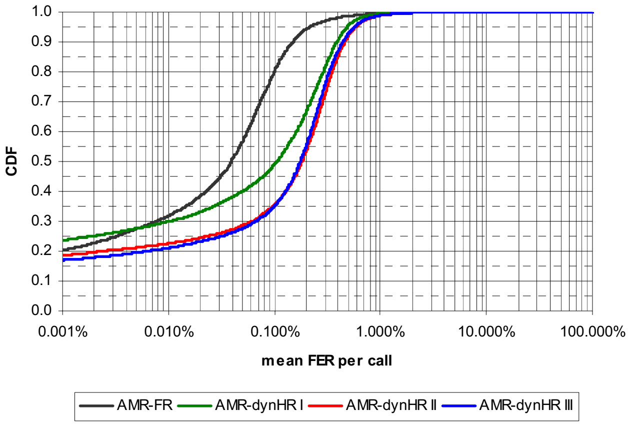

Fig. 3. CDF of mean FER per call for AMR-NB on four hopping TRX per cell for different traffic load scenarios in 4x3 re-use.

The speech quality can also be quantified by the percentage of speech samples taken over certain sampling intervals (e.g. over 4 x 480 ms) with FER higher than a specific threshold, e.g. $FER_{max} = 2.5\%$. Since such speech samples are indicating a bad speech quality, the probability (percentage) of their occurrence is termed bad quality probability BQP. The target speech quality performance is deemed satisfactory if the BQP is lower than a specific threshold, e.g. $BQP_{max} = 5\%$, called the outage probability [5]. All scenarios are well below of this limit for 4x3 re-use (see Table IV).

Table IV. Quality analysis for dynamic AMR HR allocation in 4x3 re-use.

Scenario	AMR-FR	AMR-dynHR I	AMR-dynHR II	AMR-dynHR III
mean FER < 1% [%]	99.5	99.4	98.8	98.9
mean FER < 2 % [%]	99.9	99.9	99.8	99.8
mean SCQ > 3.50 [%]	100	100	99.8	99.5
mean SCQ > 3.75 [%]	99.9	79.3	41.4	31.4
standard deviation of mean SCQ [%]	1.7	10.9	8.4	9.1
1 – BQP(FER > 2.5%)	99.4	98.0	97.5	97.7

The third quality criterion applied in this study is based on speech call quality (SCQ) analysis. SCQ represents mean opinion score (MOS) values derived from the mapping of C/I on MOS [2] for both stationary and moving subscribers. The CDF for the mean SCQ per call is shown in Fig. 4.

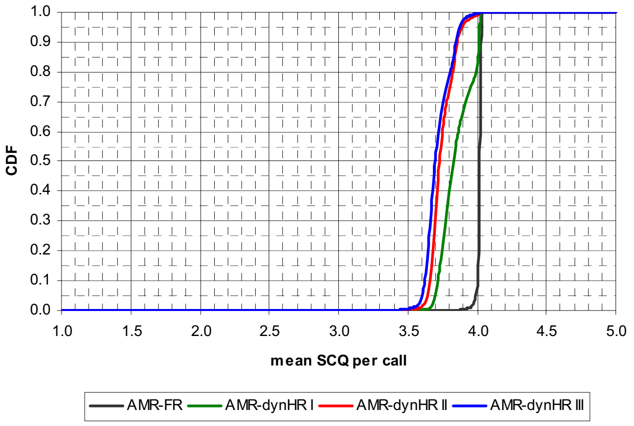

Fig. 4. CDF for the mean SCQ for pure AMR full-rate allocation and dynamic AMR-FR/HR mix at different offered load for 4x3 re-use.

The SCQ evaluation includes all phases of the call (full-rate and half-rate in case of compression/decompression). A SCQ value of 5 represents excellent speech quality, 4 marks good quality, 3 stands for fair quality, 2 represents poor quality and 1 means bad quality. AMR in full-rate offers highest homogeneity throughout the complete network area. SCQ > 3.5 is achieved on the complete cell area. The standard deviation of the mean SCQ is only 1.7%. Also all three dynamic half-rate scenarios provide mean SCQ higher than 3.5 for nearly the whole cell area. Due to the poorer quality of half-rate codecs the quality and the homogeneity are lower than for the pure full-rate scenario. However, a significant capacity gain can be observed as listed in Table III. Nearly a doubling of capacity at a maximum SCQ degradation of 0.5 MOS can be achieved (trade-off between quality and capacity).

The quality gain provided by AMR-FR/HR in comparison to EFR/GSM-HR and GSM-FR/HR is shown in Fig. 5. The CDF for mean SCQ for the dynamic half-rate scenario I has been selected for this comparison, because SCQ reflects the quality of the speech codec perceived by the subscriber. It shows also the quality difference at error free conditions, which cannot be analyzed using FER or BQP.

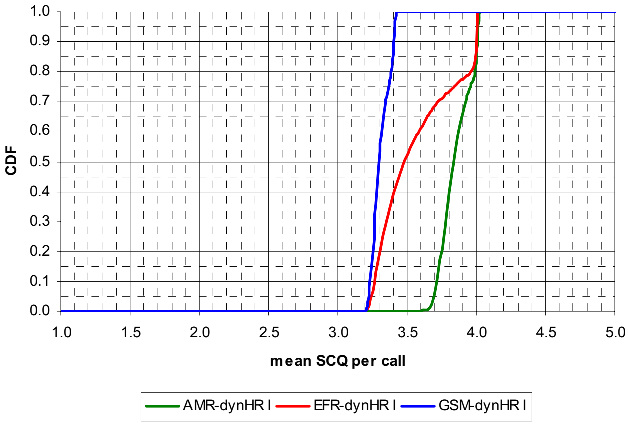

Fig. 5. CDF for the mean SCQ – comparison between AMR-FR/HR, EFR/GSM-HR and GSM-FR/HR for 4x3 re-use.

For error free conditions EFR shows the same performance as TCH/AFS12.2. Matching of the red and green curve at high C/I reflects this aspect (valid for 20% of all calls). AMR half-rate provides better speech quality throughout the complete C/I range than GSM-HR. Significant higher speech quality is obtained for AMR-dynHR compared to EFR-dynHR. The lower quality of GSM-FR in comparison to EFR and AMR full-rate is also reflected in Fig. 5.

Table V. SCQ comparison between AMR-FR/HR, EFR/GSM-HR and GSM-FR/HR combinations for dynamic half-rate scenario I.

Scenario	AMR-dynHR	EFR-dynHR	GSM-dynHR
mean SCQ > 3.50 [%]	100	47.7	0.0
mean SCQ > 3.75 [%]	79.3	28.7	0.0
standard deviation of mean SCQ [%]	10.9	27.8	6.1

C. AMR full-rate/half-rate performance in re-use 3x3

In re-use 3x3 scenarios the C/I is slightly lower than in re-use 4x3. This results only in a small (nearly negligible) quality degradation. The results are summarized in Table VI. Requiring a mean FER < 1% the 3x3 re-use results in more than 97% network coverage for all scenarios. Mean SCQ > 3.5 can be offered for more than 98% of all calls. The capacity gain is nearly in the same order as for re-use 4x3 networks.

Table VI. Quality analysis for dynamic AMR HR allocation in re-use 3x3.

Scenario	AMR-FR	AMR-dyn HR I	AMR-dyn HR II	AMR-dyn HR III
mean FER < 1% [%]	98.8	98.7	97.2	97.3
mean FER < 2 % [%]	99.6	99.8	99.4	99.3
mean SCQ > 3.50 [%]	100	99.8	99.2	98.1
mean SCQ > 3.75 [%]	99.8	69.4	32.2	25.2
standard deviation of mean SCQ [%]	2.7	12.0	9.7	10.5
1 – BQP(FER > 2.5%)	99.2	97.5	96.9	97.1
Mean number of busy channels	21.6	14.3	18.3	24.2
Mean number of vacant TS	10.4	17.7	13.7	7.8

D. AMR full-rate/half-rate performance in tight 1x1 re-use

The GSM network capacity can be significantly enhanced by tightening the frequency re-use and increasing the fractional load [6]. Advantage is taken of the high robustness of the AMR codec. In such a high capacity narrowband deployment with a huge number of TRXs installed in each cell the hard blocking threshold is no longer the limiting factor. As the traffic load increases the interference level (caused dominantly by the neighbor cells) may exceed the critical soft blocking limit at which the speech quality becomes unacceptable. At high load AMR half-rate calls cannot be served with an acceptable quality in large portions of the cell. Nevertheless calls under good radio conditions can still be compressed to half-rate mode. These calls are typically located in the inner area of the cell as shown in Fig. 6.

Snapshots for three different traffic load scenarios in re-use 1x1 for dynamic AMR half-rate mix in a high capacity network (variable number of up to 12 TRX per cell) have been

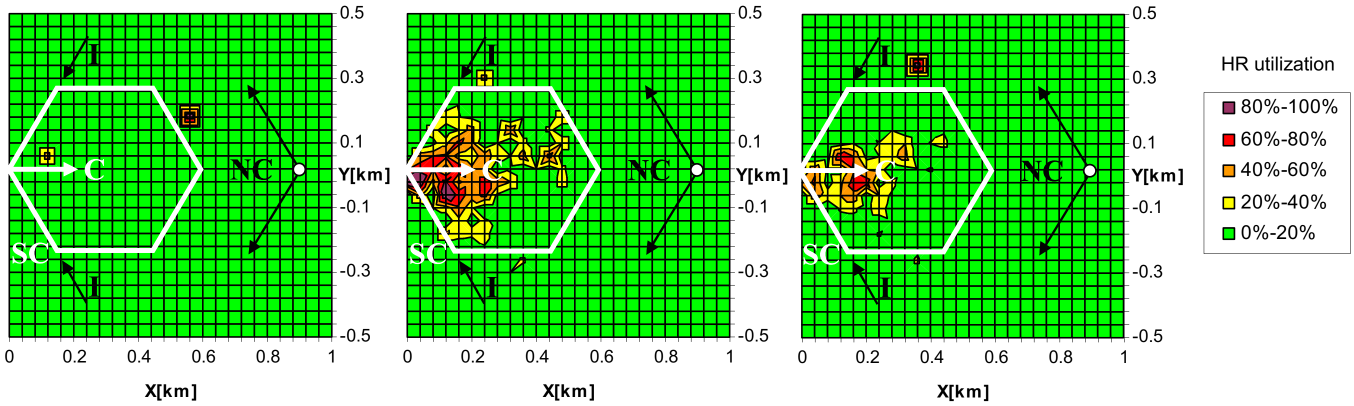

Fig. 6. Spatial distribution of the AMR half-rate utilization depending on traffic load: (a) 8 Erl, (b) 25 Erl and (c) 41 Erl.

presented. The assignment of half-rate channels is triggered at a cell load exceeding 15% Erlang fractional load (EFL) [4], [5], [8]. Load dependent decompression handover is executed if the EFL falls below 10%.

The different colors indicate the relative utilization of the half-rate codec at given lattice points of 40 m x 40 m. The base station of the serving cell (SC) is located at position x = 0 and y = 0. The site-to-site distance is 900 m. Each diagram reflects the situation for one reference cell. The three different scenarios correspond to an offered traffic load of 8 Erl (a), 25 Erl (b) and 41 Erl (c). In Fig. 6a the offered mean traffic load is lower than the half-rate activation threshold. However, due to instant traffic fluctuations exceeding 15% EFL two half-rate calls have been observed. The dark red point shows one half-rate call at the center of this diagram. The orange square in Fig. 6a indicates a relative half-rate utilization of 50%. Two subscribers are located within this grid point and one of them enjoys AMR half-rate.

Fig. 6b shows the situation for an offered traffic load of 25 Erl. The threshold defined for half-rate assignment has been significantly exceeded. This graph includes cell locations of nearly 100% half-rate utilization. An extremely high traffic load scenario of an offered load of 41 Erl is shown in Fig. 6c. The interference in the network is substantially high and the number of calls fulfilling the conditions for half-rate operation is low. Nevertheless close to the base station still a half-rate utilization of up 80% can be observed.

Fig. 7 shows the half-rate codec mode distribution for the three different load scenarios in 1x1 re-use. The codec modes 7.40 kbps and 5.90 kbps are predominantly in use for low and medium traffic load. The low interference in the network and the selection of the best suited call for half-rate operation has impact on this issue. At high traffic load a more frequent utilization of the more robust half-rate codec modes can be observed due to an increasing interference level.

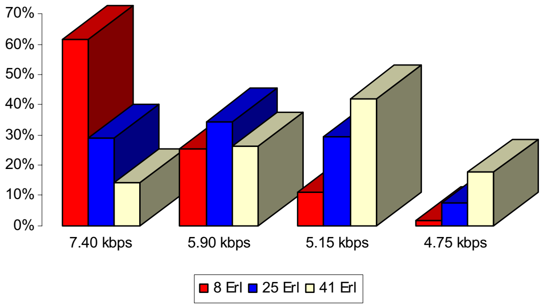

Fig. 7. Histogram of the half-rate codec mode utilization at different traffic load in tight 1x1 re-use.

Re-use 1x1 networks are soft blocked and call drop limited due to restricted robustness of FACCH/SACCH signaling channels. In tight 1x1 re-use networks the capacity can be increased up to this limit. Applying the SCQ quality criterion for TCH performance an additional capacity gain of more than 10% is obtained by enabling dynamic AMR half-rate allocation. Further capacity gain can be achieved by optimally adjusting the compression/decompression handover thresholds and power control settings. Means for interference reduction such as switched beams or interference cancellation (SAIC) can be applied in addition. Previous work on these features used for AMR can be found in [4] - [5] and [7] - [8]. Further improvement of the speech quality is achieved through the introduction of AMR-NB half-rate using 8-PSK modulation and AMR-Wideband [9], [10].

V. CONCLUSIONS

One of the major design goals in mobile networks is to provide sufficient capacity at best reachable quality. The increase of capacity and the improvement of quality are aligned. Dynamic switching between full-rate and half-rate AMR codec modes provides almost double capacity at a maximum SCQ degradation of 0.5 MOS. This is related to hard blocking limited networks in relaxed frequency re-use, in which the gain of resources can directly be used to serve additional voice subscribers and/or to increase the bandwidth for data services and thus to improve the quality of service. Additional traffic load leads to an increase of interference, however, in re-use 4x3 and 3x3 networks the impact on the quality of existing services is low. In soft blocking limited networks and tight re-use the capacity can further be enhanced by more than 10% by switching those calls to half-rate that are characterized by sufficiently good radio conditions. Thus less interference is generated in the network and the desired perceived speech quality level can be maintained while simultaneously additional subscribers are served. The simulation results show that these mobiles are mostly located close to the base station. The simulations also reveal the high performance of the proposed dynamic half-rate allocation strategy and the proper interaction between compression/decompression handover and power control.

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