Capabilities and Impacts of EDGE Evolution toward Seamless Wireless Networks

D. Mužić, D.Opatić
Mobile Networks
Ericsson Nikola Tesla d.d.
Krapinska 45, HR-10001 Zagreb
E-mail: damir.muzic@ericsson.com

Abstract - Current EDGE peak data rates of 300 kbps cannot cope with the data rates of 7.2 Mbps provided by WCDMA/HSPA networks. Still, the enormous GSM/EDGE subscriber base motivates mobile operators to continue investing in network upgrades to provide higher data rates at minimum cost. EDGE Evolution, also standardized by 3GPP, consists of a subset of features which allow to quadruple the downlink data rates compared to legacy EDGE performance. Introduction of new modulation schemes, e.g. 32 QAM and higher symbol rate will boost data rates up to 118.4 kbps per timeslot. In combination with dual downlink carrier, mobile terminals will be able to allocate ten downlink timeslots which will enable peak data rates of 1.2 Mbps. Additional improvement of EDGE Evolution end user performance will be provided by reduced latency, turbo codes and mobile receive diversity techniques. All this features together will provide comparable performances with 3G technology and more importantly, enable true service transparency between 2G and 3G networks. Implementing EDGE Evolution improvements will mostly impact mobile terminal side.

Key words – GSM, EDGE, Evolution, Seamless

I. INTRODUCTION

Commercially deployed during early 90', GSM grew to become the most widespread wireless mobile technology. Later implementation of GPRS followed by EDGE introduced data services for users all around the clock. Today GSM/GPRS/EDGE networks comprise more than 3 billion subscribers in 177 countries [Global mobile Suppliers Association - GSA, January 6, 2009]. The vast installed capacity proves the success of this technology and brings benefits in terms of omnipresent coverage, lower terminal price and cost-efficient network upgrades.

The advent of WCDMA/HSPA with data rates up 7.2 Mbps paved the way for mobile broadband and triggered more demanding services like Mobile TV, VoIP, on-line gaming, etc. Since such services are constantly increasing requirements on data rates, latency and bandwidth, current EDGE performances are not able to cope with these growing demands. Accordingly, 3GPP (3rd Generation Partnership Project) standardized a set of enhancements that will mark the development of future EDGE networks known as EDGE Evolution. The proposed improvements are included in the 3GPP Release 7 and the focus areas are latency reduction, increasing peak and mean bit rates, expanding service coverage and improving spectrum efficiency. One of the key issues embedded in the Release 7 standard is that introduction of EDGE Evolution should have minimal or no impact on legacy network equipment. Most of the proposed enhancements can be implemented in EDGE networks only with software upgrades, without requiring any hardware modification. This fact is crucial since mobile operators strive to maximize huge investments made so far in GSM/EDGE equipment. Mobile terminals will require more extensive modifications, but they are replaced at a much higher rate. EDGE Evolution puts mobile operators in a position to cost-effectively provide better data services on network wide level in a very short time.

The paper is organized as follows: Section II presents the techniques and enhancements introduced in EDGE Evolution. The expected performances are explained in Section III, with an accent on the impact that evolved EDGE features will have on legacy network hardware and mobile terminals. Conclusions are provided in Section IV.

II. EDGE EVOLUTION ENHANCEMENTS

A. Reduced latency

Latency, or round-trip-time, plays a major part for end-to-end user experience in any type of packet data application or service. For applications like VoIP or real-time gaming reduced latency is a necessity to get it to work at all. EDGE Evolution introduces substantial improvements to latency and perceived delay combining Fast ACK/NACK reporting (FANR) and reduced Transmission Time Interval (TTI).

ACK/NACK reporting is a common procedure for confirming that data packets have been correctly transmitted. Legacy procedures imply that ACK/NACK messages are sent separately from user data which inevitably increase system's reaction time. With Fast ACK/NACK reporting the acknowledgment message is embedded together with payload, so called piggybacked reporting, thus significantly reducing retransmission intervals. Additional delay reduction is achieved by sending ACK/NACK reports upon detection of RLC blocks that have not been correctly received, rather than periodically according to the legacy design base.

The second mechanism that significantly contributes latency reduction is based on sending RLC data blocks on two consecutive timeslots instead of only one, halving the TTI from 20 ms with EDGE today to 10 ms.

Combining reduced TTI and FANR it is expected to cut round-trip-times from today's values of around 135 ms down to 80 ms.

B. Downlink dual carrier

Currently EDGE is deployed only on one 200 kHz carrier. Taking in consideration that mobile terminals on the market support up to five timeslots transmitting at a peak rate of 59.2 kbps per timeslot, the maximum achievable throughput is around 300 kbps. Introducing the capability to send data on two carriers simultaneously will double the data rate in a very straightforward and backward-compatible way. The usage of the additional carrier can also be used for reducing TTI. By sending RLC blocks on timeslots on two separate carriers instead of using one timeslot on a single carrier for transmitting RLC blocks the TTI is halved. Uplink dual carrier feasibility studies are postponed in 3GPP Release 8 due to terminal implementation complexity.

C. Mobile station receive diversity (MSRD)

MSRD is included in the 3GPP Release 7 known as DARP2 (Downlink Advanced Receiver Performance phase 2). MSRD means that terminals will use dual antennas, acquiring receiver diversity on downlink. Diversity allows much more efficient interference cancellation compared to single-antenna terminals. In environments where the carrier and interfering signal are not synchronized the interference cancellation is expected to give up to 8 dB higher CIR. Besides diversity gain, MSRD provides better sensitivity since it mitigates effects of fast fading. Sensitivity increase of 3 dB can be expected bringing an increase of EDGE coverage area. Consequently, even users that are situated in areas with poor EDGE coverage will be able to achieve satisfactory data rates. Figure 1 presents data rates per timeslot achieved at different CIR using conventional receiver and dual-antenna receiver (DAIC - Dual Antenna Interference Cancellation). The simulation assumes coding schemes adaptation together with and adjacent and co-channel interference influence.

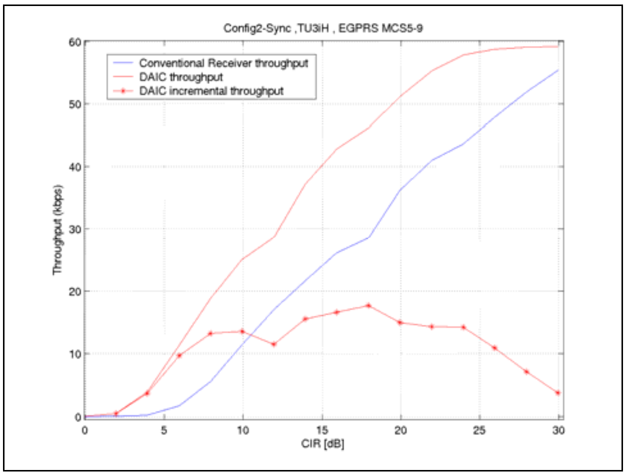

Fig. 1. Throughput per timeslot for single and dual antenna receiver [1]

MSRD and Downlink Dual Carrier both require two antennas and two receivers in the mobile terminal. Using a second receiver will inevitably increase power consumption thus drains the battery faster. It is therefore proposed to allow the MS to enable or disable the second receiver branch dependently on current battery lifetime and interference situation on the air interface.

D. Higher order modulation (HOM)

Increasing bits per symbol rate by means of higher order modulations is a very straight forward way to increase data throughput. Currently, data sent through the air interface is modulated using GMSK or 8-PSK, which allows carrying one or three bits per symbol respectively. Introduction of higher order modulation schemes, such 16QAM and 32QAM, will increase the bit per symbol rate to 4 and 5 respectively. 16QAM and 32QAM are more vulnerable to interference compared to legacy GMSK and 8-PSK modulation because of lower inter-symbol distance which tend to increase BER. However, the increased data rates from HOM can be exploited to improve the channel coding and cope with higher BER. By comparing legacy EDGE coding rates from Table 1 with those from Table 2 it can be noted that for equal user data rates, coding schemes with HOM provide more robust channel coding. Additional redundancy is then used to effectively retrieve corrupted user data even at low CIR values.

TABLE 1

BIT RATES PER TIME SLOT FOR LEGACY EDGE MCS

EGPRS			
MCS	Modulation	User Data Rate (kbps)	Coding Rate
MCS-9	8-PSK	59.2	0.71
MCS-8	8-PSK	54.4	0.60
MCS-7	8-PSK	44.8	0.47
MCS-6	8-PSK	29.6	0.63
MCS-5	8-PSK	22.4	0.49
MCS-4	GMSK	17.6	1.00
MCS-3	GMSK	14.8	0.85
MCS-2	GMSK	11.2	0.66
MCS-1	GMSK	8.8	0.53

TABLE 2

BIT RATES PER TIME SLOT FOR EDGE EVOLUTION MCS [1]

EGPRS-2 Level A Downlink			
MCS	Modulation	User Data Rate (kbps)	Coding Rate
DAS-12	32QAM	98.4	0.96
DAS-11	32QAM	81.6	0.80
DAS-10	32QAM	65.6	0.64
DAS-9	16QAM	54.4	0.68
DAS-8	16QAM	44.8	0.56
DAS-7	8-PSK	32.8	0.54
DAS-6	8-PSK	27.2	0.45
DAS-5	8-PSK	22.4	0.37
MCS-4	GMSK	17.6	1.00
MCS-3	GMSK	14.8	0.85
MCS-2	GMSK	11.2	0.66
MCS-1	GMSK	8.8	0.53

E. Higher symbol rate (HSR)

The need for higher bit rates makes favorable the use of faster symbol rate. Currently, the legacy symbol duration is 3.69 µs while EDGE evolution standardize 3.077 µs symbol duration. This reduction of symbol duration allows a 20% increase of the symbol rate, resulting in a equivalent data throughput increase. Accordingly, a wider pulse filter is required, which current base station and terminal hardware is not comprising. Thus introduction of this enhancement is not straight forward and will require modifications or replacement of legacy hardware. Table 3 shows increased data rates achieved using HSR.

TABLE 3
BIT RATES PER TIME SLOT FOR EDGE EVOLUTION MCS WITH HIGHER SYMBOL RATE [1]

EGPRS-2 Level B Downlink			
MCS	Modulation	User Data Rate (kbps)	Coding Rate
DBS-12	32QAM	118.4	0.98
DBS-11	32QAM	108.8	0.91
DBS-10	32QAM	88.8	0.72
DBS-9	16QAM	67.2	0.71
DBS-8	16QAM	59.2	0.60
DBS-7	16QAM	44.8	0.47
DBS-6	QPSK	29.6	0.63
DBS-5	QPSK	22.4	0.49
MCS-4	GMSK	17.6	1.00
MCS-3	GMSK	14.8	0.85
MCS-2	GMSK	11.2	0.66
MCS-1	GMSK	8.8	0.53

F. Turbo codes

Turbo Codes, already used in 3G WCDMA networks, are part of EDGE evolution. Turbo Codes outperform legacy convolutional codes in term of error correction, improving channel robustness and further diminishing the drawback of higher BER for HOM. At the same time, Turbo Codes are more complex than convolutional ones but existing implementation in WCDMA assure a feasible introduction also in GSM/EDGE terminals.

III. EDGE EVOLUTION CAPABILITIES AND IMPACTS

The leading idea behind evolved EDGE is that its deployment should have minimal impact on currently installed network hardware and handsets. To further facilitate introduction of EDGE Evolution improvements, the majority of the proposed features are mutually independent, allowing operators to bundle and deploy enhancements accordingly to the installed hardware capabilities.

Latency reduction improvements are the ones that are expected to hit the market first. The updates regard modification of procedures that are extensively used today, thus with no impact on networks or handsets make them favorable for an early market introduction.

HOM, turbo codes and HSR enhancements are bundled together by the name of EGPRS-2 Uplink and EGPRS-2 Downlink. HOM and turbo codes are already supported by latest base stations and can be implemented only with a software upgrade. Introduction of HSR will most probably require a new pulse shaping filter so transceivers boards on base stations will have to be replaced. To maximize the fraction of legacy hardware where these features can be implemented, different ambition levels are specified:

EGPRS-2A downlink: 8-PSK+16/32QAM+Turbo Codes
EGPRS-2A uplink: 16QAM

EGPRS-2B downlink: QPSK+16/32QAM+Turbo Codes+ Higher Symbol Rate
EGPRS-2B uplink: 16/32QAM+Higher Symbol Rate

EGPRS-2A will be the first step toward introduction of advanced coding and modulation schemes since the vast majority of currently deployed GSM/EDGE equipment provides support for those features.

Figure 2 depicts the gain that individual EDGE evolution enhancement can bring in terms of bit rate per timeslot vs. CIR. It can be denoted that a dual antenna terminal using 16QAM with turbo codes can achieve maximal bit rate at CIR around 15 dB, which is 15 dB lower compared to legacy EDGE handsets.

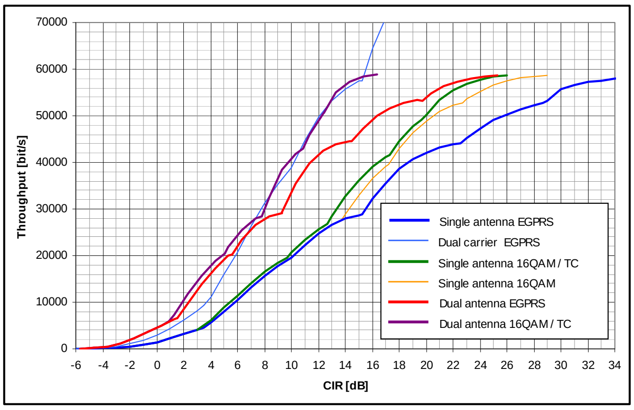

Fig. 2. Throughput per timeslot vs. CIR for different modulation and receiver combinations [1]

Predictions show that by combining EGPRS2-A downlink enhancements, MSRD and dual carrier on downlink with 5 timeslots each for a total of 10 timeslots, data rates up to 1 Mbps on downlink can be achieved in the serving cell vicinity. This is illustrated in Figure 3. This throughput is comparable to what user get from ADSL connections and not so far from HSPA data rates. This performances represents the fundament to guarantee seamless network operations between GSM/EDGE and WCDMA/HSPA networks. It is worth to remark that this prediction is based on EGPRS2-A enhancements which should not require any hardware modification in the base station. Eventual hardware constraints from terminal side can be easily surmounted due to simplicity of implementation, lower cost and shorter terminal lifetime. Even without MSRD same peak rates can be expected, although at much higher CIR levels than with MSRD.

Considering that by using 32QAM together with HSR, data rate per timeslot can be elevated up to 118.4 kbps and for state-of-the-art handsets supporting 5 timeslots together with dual downlink carrier the theoretical peak throughput can be further boosted to the maximum value of 1.184 Mbps on downlink.

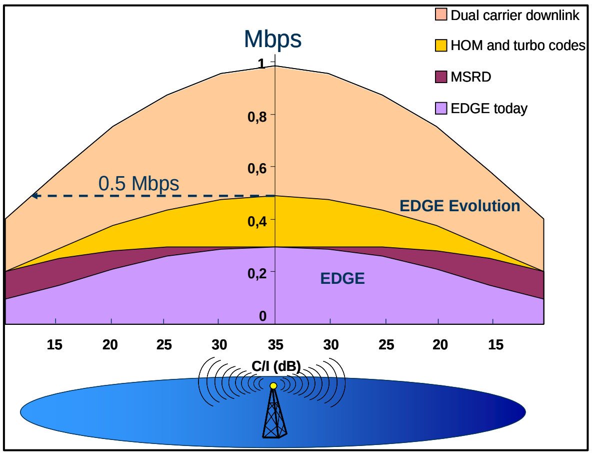

Fig. 3. Predicted user throughput with EGPRS2-A downlink and dual downlink carrier [8]

Downlink dual carrier and mobile station receive diversity (MSRD) both requires double antennas and receivers included in the handset. Implementation of MSRD and downlink dual carrier capability on 2G only phones will require and additional receive chain and an additional local oscillator as shown in Figure 4.

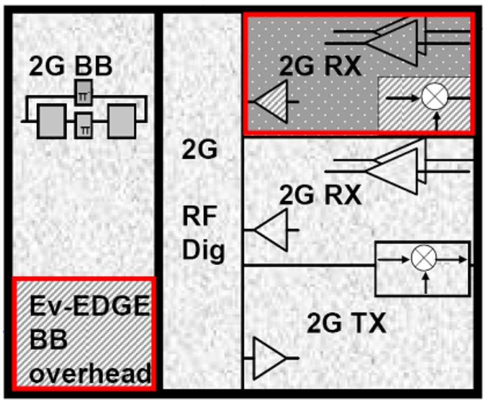

Fig. 4. Chipset view of additional EDGE Evolution requirements for 2G only terminals [7]

EDGE Evolution functions will increase the processing power requirements while the D/A interface should be upgraded to fully support all the EDGE Evolution features combined. On the other side, Multi-RAT handsets (i.e. supporting GSM/EDGE and UMTS/HSPA) offer more processing power while dual receive chain for 3G mobile receive diversity can be reused also for MSRD. Multi RAT terminals will be able to more readily incorporate features of evolved EDGE with less impact on cost and size as they leverage reuse of 3G elements, thus making them ideal fabric for a feasible implementation of EDGE Evolution features. It is expected that Multi-RAT terminal's market share will grow to reach same levels as GSM/EDGE only handsets in the next couple of years, allowing a large portion of subscriber to avail from the benefits of evolved EDGE in the very near future.

IV. CONCLUSION

This paper presents the performance concept for evolved EDGE. The key aspects of used techniques and expected performances are described together with the impact that introduction of this standard will have on mobile terminals and base station’s hardware. The evolution of EDGE will continue also in 3GPP Release 8.

Huge subscriber base and widespread coverage makes EDGE still an attractive technology for delivering data services which operators don't want to give up on. Features included in evolved EDGE allow peak data rates of 1.2 Mbps and round-trip-times down to 80 ms, keeping the pace with performances achieved by 3rd generation cellular networks. Data rates offered by EDGE Evolution provide much better complement to HSPA speeds allowing users to seamlessly roam between 2G and 3G networks without affecting service continuity. All EDGE Evolution improvements can be implemented with software upgrades only or with minimum impact on installed hardware guaranteeing a cost-efficient implementation which will further prolong the life time of this mature technology.

REFERENCES

[1] 3GPP TR 45.912 V7.2.0 (2007-02), Technical Report, “Feasibility study for evolved GSM/EDGE Radio Access Network (GERAN)”, Release 7

[2] P. Chitrapu, B. Aghili, “Evolution of GSM into the Next Generation Wireless World”, IEEE Systems, Applications and Technology Conference, Long Island, 2007

[3] K. Ivanov, C.F. Ball, R. Müllner, H. Winkler, “Paving the Path for High Data Rates by GERAN Evolution EDGE2 with Dual-Carrier”, IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, Cannes, 2008.

[4] M. Säily, J. Hulkkonen, O. Piirainen, K. Niemelä, E.B. Zacarías, “EGPRS2 Uplink Performance for GERAN Evolution”, IEEE Vehicular Technology Conference, Singapore, 2008.

[5] M.L. Roberts, M.A. Temple, R.F. Mills, R.A. Raines, “Evolution of the Air Interface of Cellular communications Systems Toward 4G Realization”, *IEEE Communications Surveys & Tutorials journal*, Vol. 8, No.1, p.2-23, 2006

[6] T. Halonen, J. Romero, J. Melero “GSM, GPRS and EDGE Performance: Evolution Towards 3G/UMTS”, 2nd Edition, John Wiley, 2003.

[7] “The Case for Evolved EDGE”, 3G Americas White Paper, 2008

[8] “The Evolution of EDGE”, Ericsson White Paper, 2007.