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THE EVOLUTION OF EDGE

February 2007

White Paper

With EDGE Evolution higher data rates and improved coverage will be introduced, further strengthening GSM/EDGE as being an attractive mobile broadband solution and complement to HSPA

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Contents

1 Executive summary

Since its standardization was finalized by the 3GPP in year 2000, EDGE – Enhanced Data rates for Global Evolution – has achieved market maturity in terms of networks, terminals and business models. Upgrading to EDGE has become a natural step for operators who want to offer high-performance mobile data services over GSM. EDGE gives them a cost-efficient way to reach the mass market to boost the uptake of mobile data services. Market data reveals that, on average, EDGE users consume up to three times as much data as standard GPRS users.

EDGE combines efficient technology, a simple upgrade path, and support in a large proportion of GSM and WCDMA terminals to create a compelling business case. Half of all mid- and high-end GSM terminals sold now support EDGE, and there is a clear trend towards EDGE being supported in low-end terminals as well. EDGE is becoming a viable alternative for providing Internet access in markets where fixed network infrastructure is yet to be established.

The performance of EDGE has improved steadily since its introduction: today it offers user bit-rates of around 250 kbit/s, with end-to-end latency of less than 150 ms. This performance is sufficient to make any data service available today attractive for users.

EDGE is an important complement to mobile broadband services delivered today over WCDMA/HSPA and in the future LTE networks. EDGE provides both a fast way to achieve good indoor and outdoor coverage, and to meet increasing demand for mobile Internet services through optimal use of available radio spectrum.

To build on the global success of EDGE, the GSM community is in the process of standardizing EDGE Evolution, which will further improve performance, efficiency and other capabilities. EDGE Evolution will more than double end-user bit-rates and reduce latency significantly. What is more, all this can be done using existing infrastructure, protecting current GSM and EDGE investments for many years to come.

2 The GSM/EDGE advantage

In the mid-1990s GSM deployment gathered pace around the world, and this growth continues today. More than 80 per cent of all mobile users in the world are served by GSM, and every month another 30–40 million new users join the GSM community. As a mobile technology, the coverage, economies of scale, simplicity and maturity of GSM are unmatched, and these are all benefits that EDGE shares too.

Standardized in 3GPP as part of the GSM/WCDMA family, EDGE is a simple and cost-efficient upgrade that provides a more than three-fold increase in both the capacity and performance of GSM/GPRS networks. It does this by introducing sophisticated methods of coding and transmitting data, delivering higher bit-rates per radio channel, as illustrated in Figure 1.

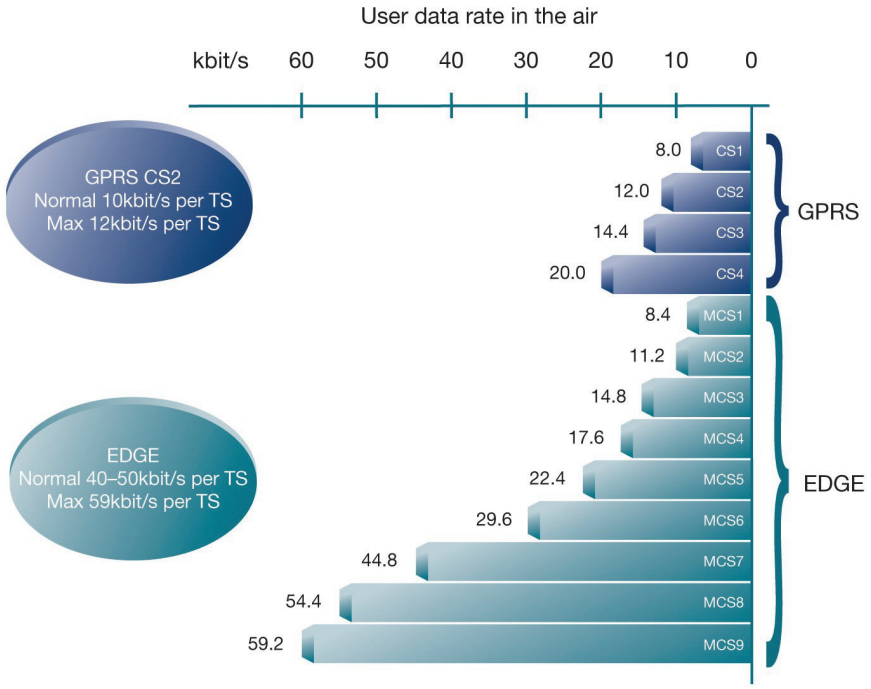

Figure 1. EDGE is four times as efficient as GPRS. GPRS use four coding schemes (CS-1 to 4) while EDGE use nine Modulation and Coding Schemes (MCS-1 to 9). Bitrates stated are per timeslot, today's terminals receive data on up to five timeslots.

Introducing EDGE normally only requires a software upgrade of the existing GSM/GPRS network: it does not require any new sites or new spectrum, and has no impact on existing cell or frequency plans.

With EDGE, GSM operators are able to extend their service offering to include high-performance mobile data. They can rapidly target all potential data users thanks to EDGE's ability to achieve high geographic and population coverage in a short period of time. This is one of the main reasons that several hundred GSM networks have already upgraded to EDGE, or are in the deployment phase. EDGE is not launched as a service: it is an enabler of new services and faster Internet access – a virtually mandatory upgrade, with a clear and compelling business case.

2.1 Making mobile Internet happen

Mobile phones and the Internet are an increasingly important part of people's day-to-day lives. Now, thanks to the advances being made in mobile networks and terminals, these two invaluable technologies are coming together. Mobile data rates are getting higher, prices are coming down, and services are becoming more user-friendly.

EDGE-delivered data services create a broadband Internet-like experience for the user on the mobile phone. And the signs are that users like it. Measurements from many markets show that users with EDGE-enabled services consume up to three times more data than standard GPRS users – generating a positive data ARPU (Average Revenue Per User) contribution.

There are still many markets where 3G networks have not been deployed, or where licensing regulations have not even been settled. In these markets, EDGE offers sufficient bandwidth to deliver fast Internet access over the existing GSM infrastructure. The combination of mobile broadband capability and low-priced EDGE-capable GSM phones makes EDGE a very interesting and viable option for markets where fixed network infrastructure is yet to be established.

2.2 EDGE filling the gap between GPRS and 3G

Mobile data services offer a clear way to create new services and differentiate from the competition, to attract new customer segments and reduce churn. Mobile operators need a business model based on differentiated service levels and a clear market segmentation strategy. In this context, investment in superior services for high-end user segments is justified, as these customers generate the lion's share of revenue.

EDGE helps operators adopt a more flexible approach to customer segmentation based on price and performance, filling the service gap between standard GPRS and WCDMA/HSPA, as illustrated in Figure 2.

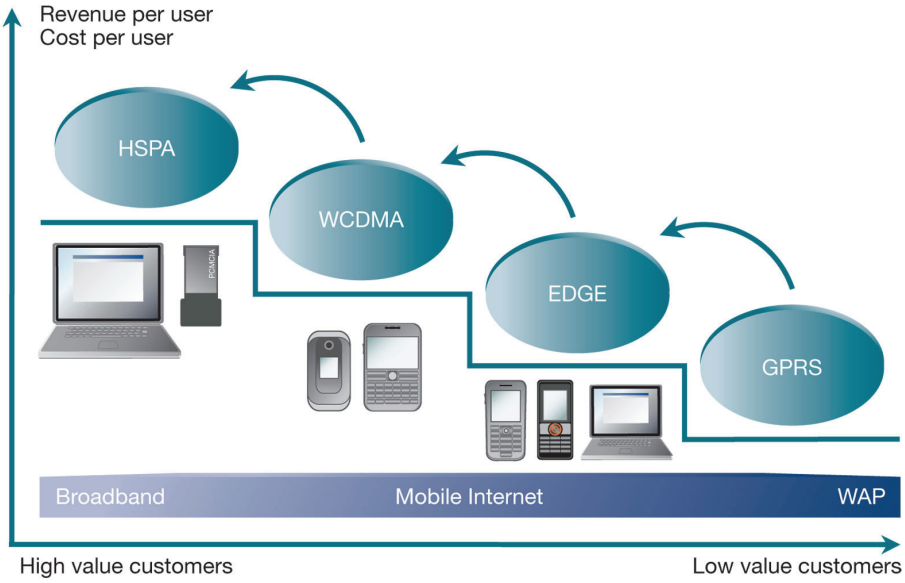

Figure 2. Market segmentation by packet switched data capability.

End-users are not too worried about terms like ‘2G’ and ‘3G’ when they buy a new mobile handset. They care about brand identity, handset design, battery time, camera and music playback capabilities and, of course, price. Data connectivity features are not well understood, and it is mainly down to the operator what customers get in terms of voice and data bundling.

By taking control of handsets, operators can create a sustainable end-user relationship, with guaranteed end-to-end service functionality, to achieve higher brand recognition. This also helps operators control network utilization efficiently, in either the GSM or the WCDMA networks, by offering terminals with preferred connectivity.

2.3 Vast majority of handsets supporting EDGE

The success of any new mobile technology is closely tied to the alignment of handset and network functionality. The larger and more complex the mobile community and environment, the bigger the effort needed to drive through a new technology. EDGE is well past the critical phase, and is supported by all major chip vendors for both GSM and WCDMA/HSPA. There is a clear trend towards EDGE becoming a basic feature in a vast majority of 3GPP-compliant terminals, as shown in Figure 3.

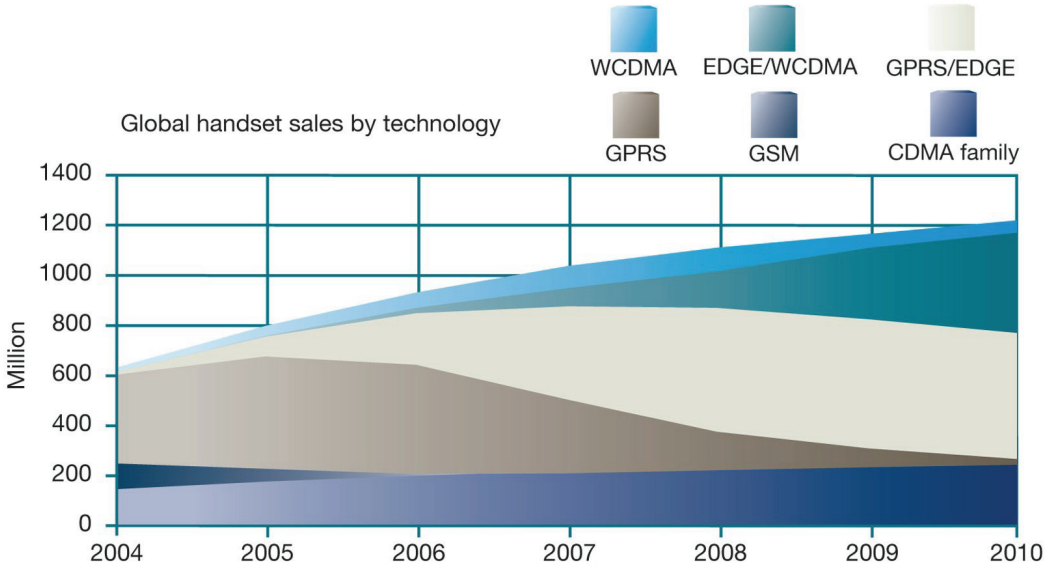

Figure 3. New sales by technology. (source: Strategy Analytics, 2006)

2.4 Enabler of the seamless network vision

Industry experts are predicting a continuing mobile traffic explosion, fuelled by cheaper and more efficient terminals and networks, in combination with lower tariffs and increased interest in mobile data services. The seamless network vision is about creating the best and most cost-efficient network environment to support this trend.

Billions of dollars have been invested in 2G legacy infrastructure, and it is vital that its technical and economic lifecycle is prolonged as much as possible. In the seamless network vision, end-user applications are independent of access network technology. Data and voice traffic are steered to available and capable network resources by advanced algorithms and rules that optimize network resource utilization.

Thanks to its excellent multiplexing ability, EDGE has proved to be a cost-efficient technology especially for data traffic requiring low throughput. With both 2G and 3G deployed, EDGE can play an important role in load balancing, improving network capacity, and as a coverage complement to 3G. Rising traffic levels also imply the need for better spectrum utilization, and EDGE can help operators get the most out of existing investments.

2.5 EDGE reduces total cost of ownership

It makes sense for any existing GSM operator offering data over GPRS to upgrade to EDGE from a pure network efficiency point of view. EDGE enables more Megabytes to be carried at lower cost, and improves data service coverage in a short time. Studies show that data traffic will take off when EDGE is introduced and the additional cost in terms of radio infrastructure is limited, thanks to the efficiency of EDGE, as illustrated in Figure 4.

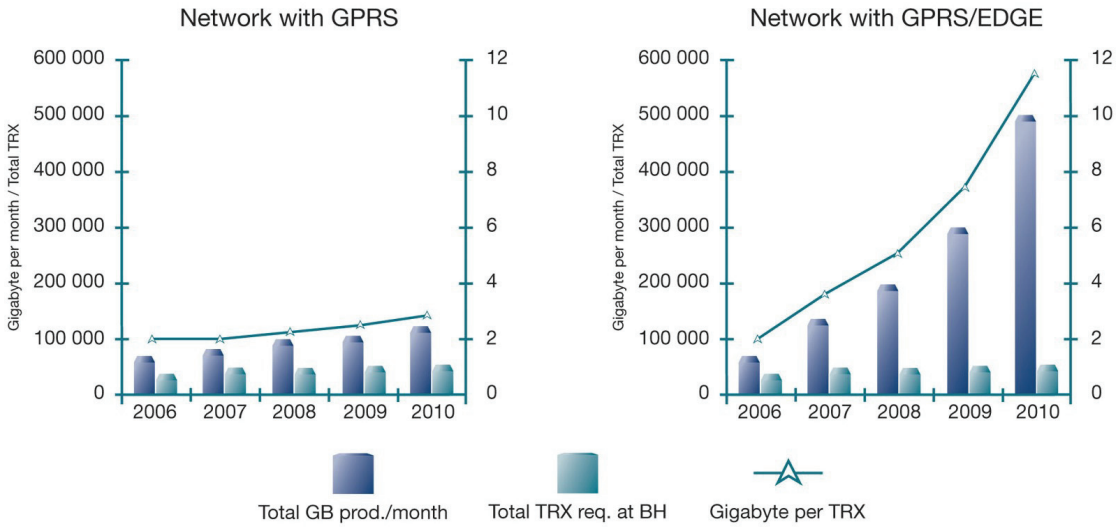

Figure 4. Data volume (Gigabyte) and required number of TRX (at Busy Hour) forecast for a major Asian city. Source: Ericsson

All popular data applications available today work well over EDGE. From an end-user perspective, there is little difference in performance between WCDMA R99 and EDGE. For an operator this means flexibility in the deployment of new network infrastructure. With EDGE deployed, the issue of how, when and where to roll out WCDMA/HSPA capabilities are not governed by licensing requirements, but by current and future bandwidth demand. EDGE optimizes Total Cost of Ownership (TCO) for the operator, with performance that will meet market demand in many areas for years to come.

3 EDGE performance today and tomorrow

Today's EDGE technology offers greatly improved performance compared with standard GPRS and the first implementations of EDGE. The increased user bit-rates and reduced latency offered by EDGE today enhance existing applications and make new services like music downloads, mobile TV and messaging services more attractive to users.

3.1 Network performance of today

The performance of EDGE, as experienced by the end-user, is dependent on a variety of system characteristics. For example, a web download consists of multiple requests and downloads of objects and, consequently, the time it takes to download the page depends on the end-to-end round-trip time and user bit-rates in the system – which are the main performance indicators for any packet data system. Performance is normally evaluated across a common set of subscriber applications.

Today's state-of-the-art EDGE networks typically offer user speeds of 200 kbit/s, and 250 kbit/s in peak, with end-to-end round-trip time (latency) of 150 ms (as shown in Figure 5). Features like advanced link quality control and persistent scheduling have improved performance significantly over standard GPRS and the first implementations of EDGE. For example, the time it takes to download a web page is about one-quarter that taken with standard GPRS.

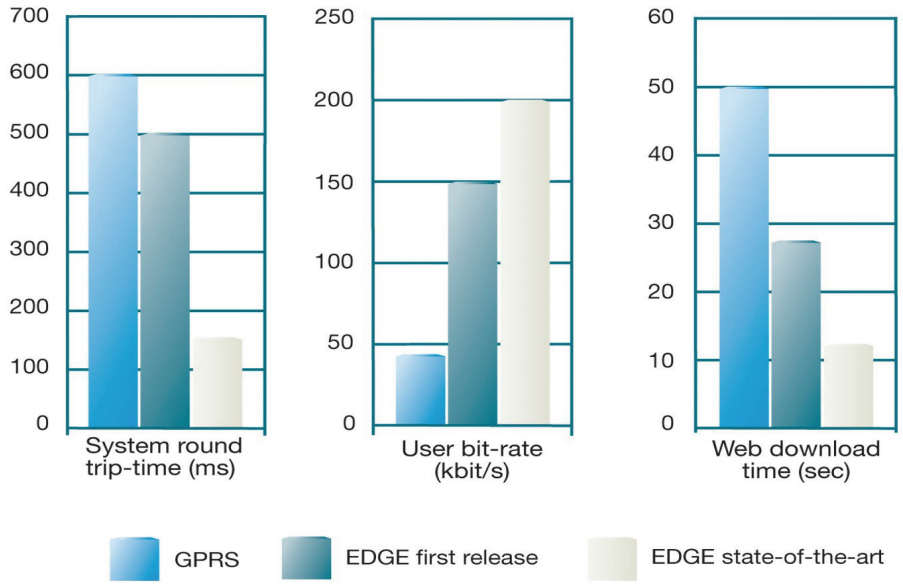

Figure 5. Typical live network performance indicators and application performance.

3.2 Enhanced applications performance over EDGE

EDGE enhances services provided by 2G systems with higher user bit rates and multi-media capabilities. EDGE is also an evolutionary path towards providing third-generation services.

The perceived end-user performance enabled by EDGE is good enough to make any service available today attractive (Table 1). This includes e-mail, web browsing, music download and mobile TV.

Application	**Benefit with EDGE**
Web browsing	Significantly faster browsing for all data users
Messaging	Much faster interaction – good for chat environment
E-mail	Synchronization of mail accounts significantly faster
Push-to-Talk	Significantly improved end-user quality and higher capacity
Gaming	Real-time gaming is enabled
Mobile TV	Good TV quality is enabled
Music download	Good experience with EDGE and progressive download

Table 1. Services enhanced over GSM/EDGE.

3.3 EDGE Evolution performance boost

To improve service performance in general, and facilitate conversational multimedia services, a number of enhancements to EDGE have been standardized in 3GPP. Known collectively as EDGE Evolution, these are included in Release 7 of the 3GPP standard. Peak bit-rates of up to 1 Mbit/s and typical bit-rates of 400 kbit/s can be expected. Round-trip times will be less than 100 ms and spectrum efficiency will be more than twice as good as today. EDGE Evolution can be gradually introduced as software upgrades, taking advantage of the installed base. With EDGE Evolution, end-users will be able to experience mobile Internet connections corresponding to a 500 kbit/s ADSL service.

EDGE Evolution will improve service performance and enable more efficient radio bearers. Different services may have different performance requirements in different areas, but EDGE Evolution is expected to improve the user-experienced performance across all services by:

- Reducing latency to improve the user experience of interactive services and also to enhance support for conversational services such as multimedia telephony
- Increasing peak and mean bit-rates, to improve best-effort services such as web browsing or music downloads
- Improving spectrum efficiency, which will particularly benefit operators in urban areas where existing frequency spectrum is used to its maximum extent – traffic volume can be increased without compromising service performance or degrading perceived user quality
- Boosting service coverage, for example through interference reduction or more robust services. Increased terminal sensitivity improves coverage in the noise-limited scenario.

3.4 Implementing EDGE Evolution

The installed base of GSM/EDGE equipment is very large, so great care has been taken to ensure that the impact of EDGE Evolution on base station hardware is minimized. The different enhancements may be gradually – and to some extent independently – introduced in the network, most of them as software upgrades. Current network architecture remains unchanged.

Terminals will require more extensive modifications, but are replaced at a much higher rate. A large number of handset vendors will adhere to EDGE Evolution, and handsets with increasing levels of EDGE Evolution functionality are expected to be available from 2008.

Figures 6 and 7 show examples of the increased peak bit-rates and spectrum efficiency provided by GPRS, EDGE and different stages of EDGE Evolution implementation.

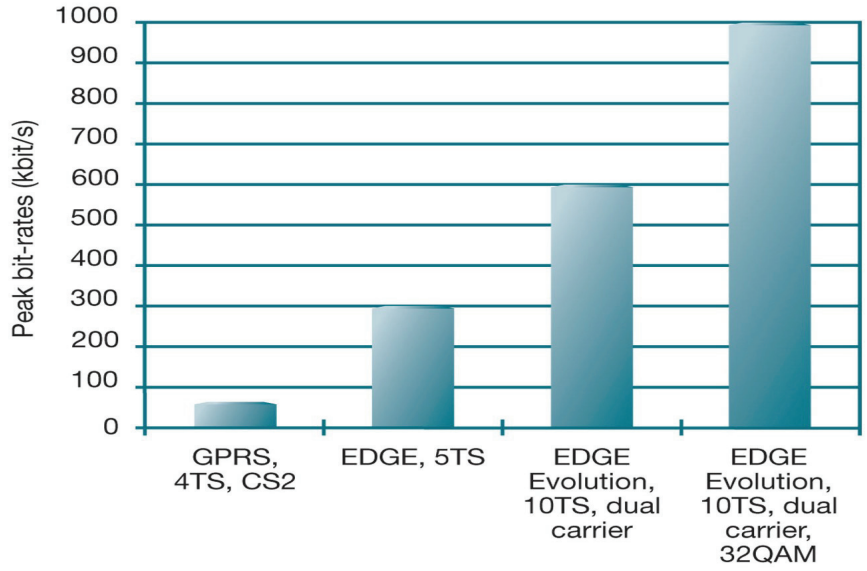

Figure 6. Peak bit-rates in downlink for GPRS, EDGE and different stages of EDGE Evolution.

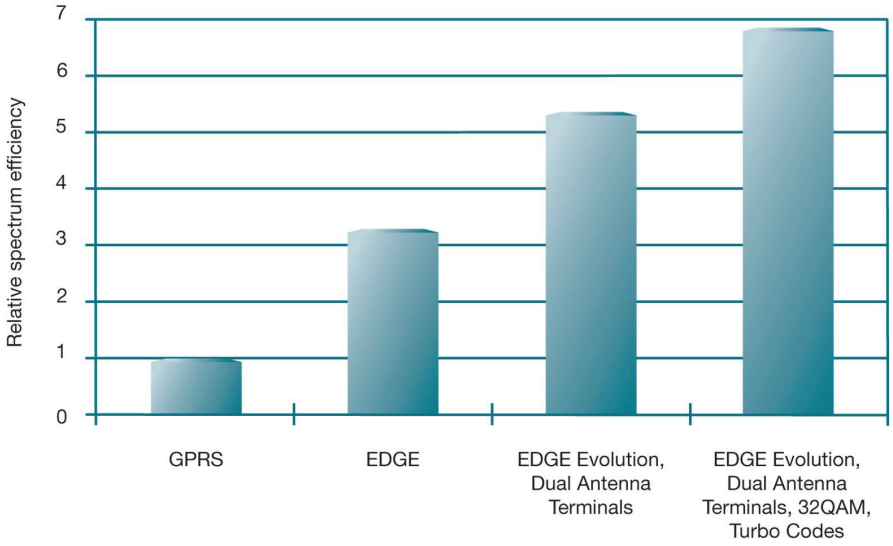

Figure 7. Relative spectrum efficiency for GPRS, EDGE and different stages of EDGE Evolution

4 The evolution of EDGE technology

EDGE is an improvement to the GPRS air interface that enables higher user bit-rates and greater system capacity by enhancing the physical layer. The higher bit-rates place extra demands on parts of the GPRS network (as shown in Figure 8). The core GPRS nodes, SGSN and GGSN, are more or less independent of user bit-rates and no new hardware is required. In the radio network, base station transceivers need to be EDGE-capable, and base station and BSC/PCU software needs to be updated.

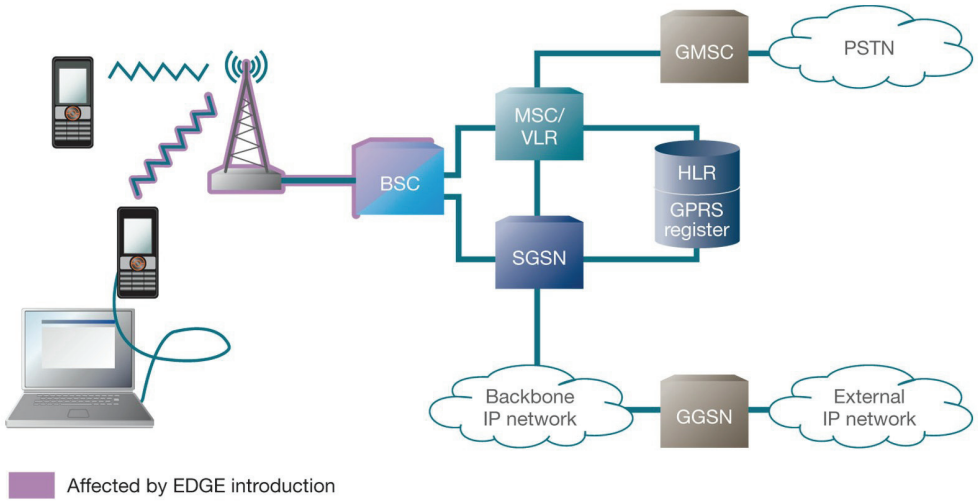

Figure 8. GSM/GPRS network architecture.

One fundamental characteristic of cellular systems is that different users experience different channel quality, as a result of differences in the distance to the serving base station, fading and interference. Radio network planning ensures that only a fraction of users ever experience low channel quality, but also means that many users have ‘excessive’ channel quality.

EDGE improves the situation by employing a new modulation method and link quality control. 8-PSK (as illustrated in Figure 9) is a high level linear modulation method that carries three times more information through an extended signal constellation. GMSK modulation, as defined in GSM/GPRS, is also part of EDGE.

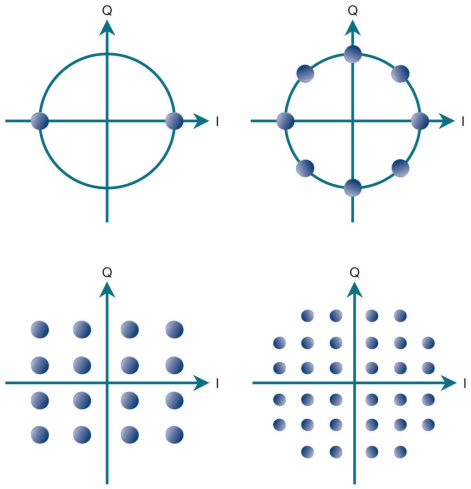

Figure 9. Top left: Gaussian minimum-shift keying (GMSK) – 1 bit per symbol. Top right: Octonary phase shift keying (8-PSK) – 3 bits/symbol. Bottom left: 16QAM: 16-level constellation – 4 bits/symbol. Bottom right: 32QAM: 32-level constellation – 5 bits/symbol.

Nine modulation and coding schemes are defined in EDGE. Link quality control dynamically selects the modulation and coding scheme for transmission of data over the air interface. The protection of the data is adapted to the channel quality to obtain optimal bit-rate. Standard GPRS bit-rate saturates at relatively low channel quality, whereas EDGE user bit-rates increase with better channel quality. Link quality control in EDGE uses both link adaptation and incremental redundancy where the initial coding is selected based on measurement of radio quality and additional redundancy is sent if decoding fails. As illustrated in Figure 10, incremental redundancy gives higher bitrate and higher robustness compared to link adaptation.

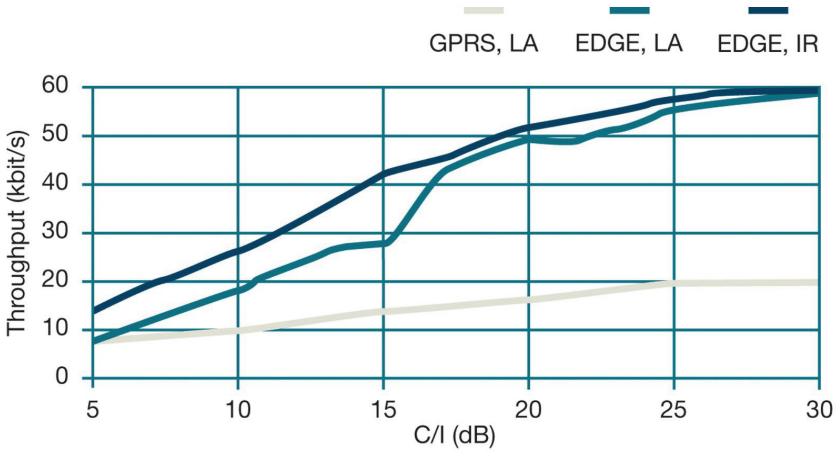

Figure 10. Bitrate per timeslot as a function of radio quality for GPRS, EDGE Link Adaptation and EDGE Incremental Redundancy

4.1 EDGE Evolution enhancements

4.1.1 Latency reduction

EDGE Evolution makes substantial improvements in latency and perceived delay through reduced Transmission Time Interval (TTI) and additional protocol enhancements. Radio blocks are currently transmitted over four consecutive bursts on one timeslot using a TTI of 20 ms. Reducing the TTI to 10 ms improves latency substantially, to below 100 ms. The four bursts are then transmitted on more than one timeslot (parallel timeslots on two carriers or dual timeslots on one carrier).

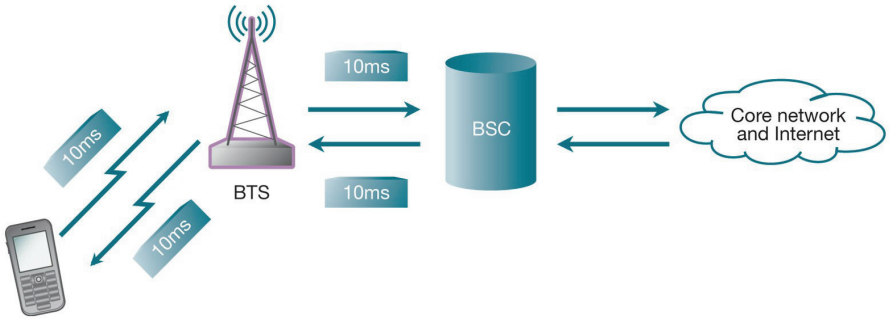

Figure 11. Lower latency with reduced TTI.

4.1.2 Increased bit-rates and improved efficiency

Dual carriers

The most obvious improvement to peak bit-rates is through the introduction of dual carriers in the downlink, increasing the carrier bandwidth available above 200 kHz. EDGE terminals already use multiple timeslots for transmission and reception. Today's terminals receive on up to five timeslots. The introduction of dual carriers doubles the available bandwidth (to 400 kHz) as well as the practical peak bit-rate. Using dual carriers and five timeslots on each carrier provides bit-rates of almost 600 kbit/s, with no other changes to EDGE.

Higher-order modulation, turbo codes and increased symbol rate

Higher average and peak bit-rates and improved spectrum efficiency are achieved through more advanced modulation, more efficient channel coding and an increased symbol rate (in practice, increasing the carrier bandwidth).

Using 16QAM instead of 8-PSK modulation for some of the current Modulation and Coding Schemes (MCS) improves robustness against interference and, as a result, increases the average bit-rates. In this case, the higher number of bits per symbol (see figure 9), is used to increase the channel coding. Using so called 'turbo codes', which handle error correction more efficiently than current convolutional codes, improves average bit rates even further.

With twelve MCSs – three more than with regular EDGE – enabled by higher-order modulations (16QAM and 32QAM in addition to GMSK and 8-PSK), the peak bit rate is boosted to 100 kbit/s per timeslot, equating to user bit-rates of 1 Mbit/s if dual carriers are used. The higher symbol rate enables higher bit-rates in the uplink, since dual carriers are only standardized for the downlink.

Dual-antenna terminals

Dual-antenna terminals enable efficient interference rejection techniques, similar to those used in base station receivers. By combining signals from the two antennas, a large proportion of the interference can be cancelled out, significantly improving average bit-rates and spectrum efficiency.

Figure 12 shows an example of different bit-rates in a cell, as different features are introduced. It shows how higher-order modulation and dual carriers improve peak bit-rates, while higher-order modulation, turbo codes and interference cancellation with dual antennas increase bit-rates at the cell border.

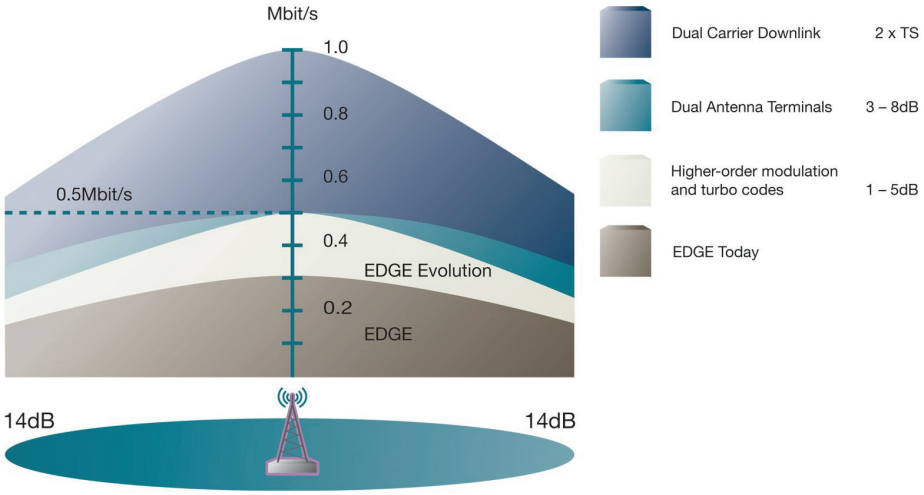

Figure 12. Examples of bit-rate improvements in different parts of a cell.

4.1.3 Service coverage

Dual antenna terminals can also improve service coverage. With two antennas and efficient combination methods, weaker signal transmissions can be captured. Around 3 dB less (roughly 50 per cent) signal power is needed to provide service, enabling larger cells or lower output power.

5 Conclusion

EDGE is delivering high bit-rates and spectrum efficiency for GSM operators around the world, and is becoming a standard capability of GSM and WCDMA phones. In effect, EDGE enables 3G applications over current GSM networks, and provides seamless services with 3G.

Today, EDGE enables user bit-rates of 250 kbit/s and a latency of 150 ms. This means it can handle four times as much traffic as standard GPRS, increasing the usability of mobile data services, enhancing customer satisfaction and boosting data revenues.

EDGE Evolution, currently being standardized in 3GPP, will improve performance and coverage even further, with bit-rates of up to 1 Mbit/s and latency below 100 ms.

For GSM operators around the world, this makes the business case for EDGE even stronger than it is today – whether or not they have access to 3G spectrum.

6 Glossary

3G: Third generation radio technology for mobile networks. Narrowband digital radio is the second generation of technology (2G).

3GPP: Third Generation Partnership Project

8-PSK: Eight-Phase Shift Keying

16QAM: 16-point Quadrature Amplitude Modulation

32QAM: 32-point Quadrature Amplitude Modulation

BSC: Base Station Controller

CDMA: Code Division Multiple Access

EDGE: Enhanced Data rates for Global Evolution

GGSN: Gateway GPRS Support Node

GMSK: Gaussian Minimum Shift Keying

GPRS: General Packet Radio Service

GSM: Global System for Mobile communications

HLR: Home Location Register

HSPA: High Speed Packet Access

LTE: Long Term Evolution

MCS: Modulation and Coding Scheme

MSC: Mobile Switching Center

PCU: Packet Control Unit

SGSN: Serving GPRS Support Node

TTI : Transmission Time Interval

VLR: Visitor Location Register

VoIP: Voice over Internet Protocol technology enables users to transmit voice calls via the Internet using packet-linked routes. VoIP is also called IP telephony.

WCDMA: Wideband Code Division Multiple Access