Handover between WCDMA and GSM

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Handover between WCDMA and GSM allows the GSM network to be used to give fallback coverage for WCDMA technology. This means that subscribers can experience seamless services—even with a phased build-out of WCDMA—which is of importance to the commercial launches in 2003. As the leading total system provider, Ericsson has developed technologies that overcome the challenges of interworking between WCDMA and GSM. For example, Ericsson was first to demonstrate handover from WCDMA to GSM in a live network.

In this article, the authors describe features such as cell re-selection between WCDMA and GSM, compressed mode measurements, the WCDMA-to-GSM cell-change order, handover from WCDMA to GSM, and handover from GSM to WCDMA.

BOX A, TERMS AND ABBREVIATIONS

3GPP	Third-generation Partnership Project
BSC	Base station controller
BSS	Base station subsystem
CN	Core network
GSM	Global system for mobile communication
IP	Internet protocol
MMS	Multimedia messaging service
MT	Mobile terminal
PDU	Protocol data unit
RAT	Radio access technology
RBS	Radio base station
RF	Radio frequency
RNC	Radio network controller
SMS	Short message service
SRNS	Serving radio network subsystem
UMTS	Universal mobile telecommunications system
UTRAN	UMTS terrestrial radio access network
WCDMA	Wideband code-division multiple access

Introduction

Third-generation mobile services are now being introduced throughout the world. Wideband code-division multiple access (WCDMA) technology is an excellent framework for providing these services, since it meets the performance demands of the Mobile Internet, including Web access, audio and video streaming, and video and IP multimedia calls. Ericsson has been a main contributor during the development of WCDMA technology, and many operators have selected Ericsson as their vendor of WCDMA infrastructure.

Although the WCDMA technology will initially only be deployed to cover urban areas, many operators still feel the need to provide nationwide coverage from the very start. The GSM networks have a global footprint that provides access to mobile services, such as voice, circuit-switched and packet-switched data, short message service (SMS) and multimedia messaging service (MMS). Those operators who already have a GSM network want to capitalize on their investments when migrating to WCDMA technology. A third-generation mobile terminal equipped with both WCDMA and GSM technology would put the end-user in contact with seamless, (practically) worldwide, mobile service.

Dual-mode WCDMA-GSM mobile terminals of this kind require an interworking mechanism between the WCDMA and GSM technologies. For instance, if the user has established a voice call using WCDMA technology, and then moves outside of WCDMA coverage, the voice call needs to be handed over to GSM without any perceived disturbance.

Ericsson was first to demonstrate WCDMA-to-GSM handover using dual-mode mobile terminals in a live network. In the demonstration, Ericsson was a total system provider, supplying the network infrastructure and the mobile terminals. Handover is a key feature for ensuring interworking between WCDMA and GSM technologies. Ericsson has been a main driver during each phase of the development of interworking between WCDMA and GSM, which included research, standardization, product development and multi-vendor testing. Below, we describe in greater detail the key features of this interworking.

Main challenges

Several challenges had to be overcome to achieve interworking between WCDMA and GSM. First, to get feasible technical solutions for the mobile terminal and network implementations, some restrictions had to be set. For example, in the early discussions it was proposed that the mobile terminal should be able to have a voice call in WCDMA while sending data in GSM. However, this capability was restricted in the standard, allowing the mobile terminal to communicate with only one of the technologies at a time (WCDMA or GSM).

Another challenge was to minimize the changes to the existing GSM infrastructure. The solution encapsulates messages in "containers." As seen in Figure 1, when the network sends a message in WCDMA, to order handover to GSM, part of the WCDMA message includes a GSM message, which looks exactly the same as if it had been sent on the GSM radio interface. This part of the WCDMA message is extracted in the mobile terminal and processed as if it had been received as a regular GSM message in GSM. The same principle is used for handover from GSM to WCDMA, and when information is passed on the interfaces between network nodes.

For handover from GSM to WCDMA, the length of the handover message is also an important factor, since handover performance deteriorates with larger handover messages. Likewise, the bit rate of the GSM radio interface limits its ability to carry large WCDMA handover messages. To handle this situation, instead of signaling each parameter of the actual configuration, the network can signal a small size reference to a pre-defined WCDMA radio channel configuration, which is either stored in the mobile terminal (default configuration) or sent to the mobile terminal in broadcast mes-

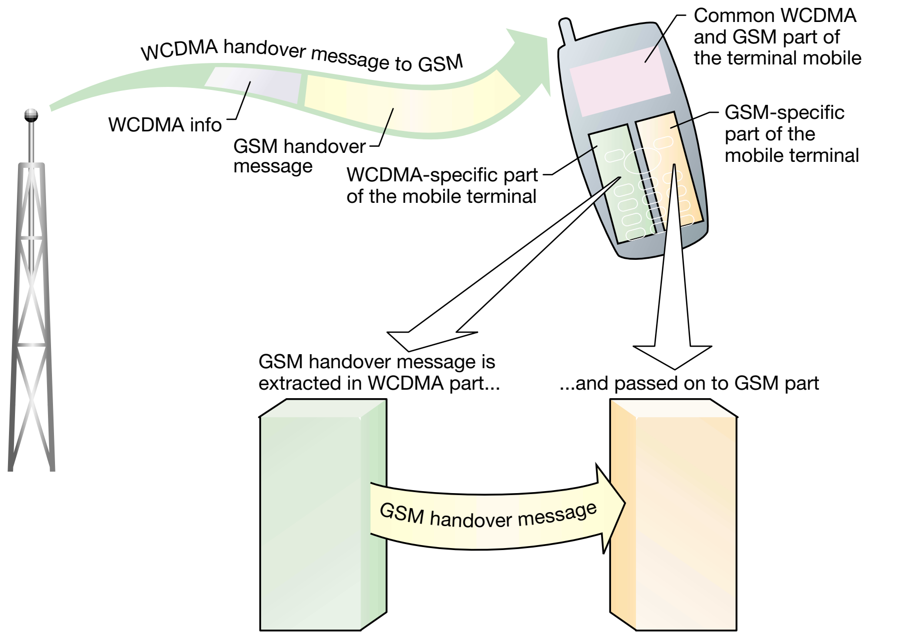


Figure 1
Encapsulation of the GSM handover message in a "container" that is part of the WCDMA handover message.

sages. The pre-defined WCDMA radio channel configuration describes bit rates, data block sizes and other radio parameters of voice or video call service.

Although the network solely communicates with the mobile terminal using one access technology at a time, the mobile terminal needs to perform measurements on GSM while communicating in WCDMA and vice versa. Since WCDMA uses continuous transmission and reception in active mode, a regular mobile terminal cannot measure GSM cells while communicating in WCDMA. To overcome this obstacle, Ericsson has introduced what it calls the compressed mode method. As seen in Figure 2, a short gap is created in transmission and reception. To maintain a perceived constant bit rate, the actual transmission bit rate is increased just before and after the gap. A constant bit rate is required for services such as voice, but for Web browsing and similar services, a constant bit rate is not necessary. In the latter case, the transmission can thus be delayed to create a gap. When the mobile terminal is not in active mode it uses discontinuous transmission and reception, and can therefore measure GSM cells.

Since WCDMA and GSM are different technologies, it is difficult to compare the measurement results from these technologies. To overcome this challenge, the measured results are compared with a technology-specific threshold. Furthermore, additional parameters, such as adjustable offsets, are provided to control the selection between WCDMA and GSM cells. Where the GSM measurement of WCDMA cells is concerned, the main challenge is to fit the information into existing GSM messages.

Figure 2
Compressed mode creates gaps or idle spaces in time that WCDMA mobile terminals use to perform measurements on GSM cells.

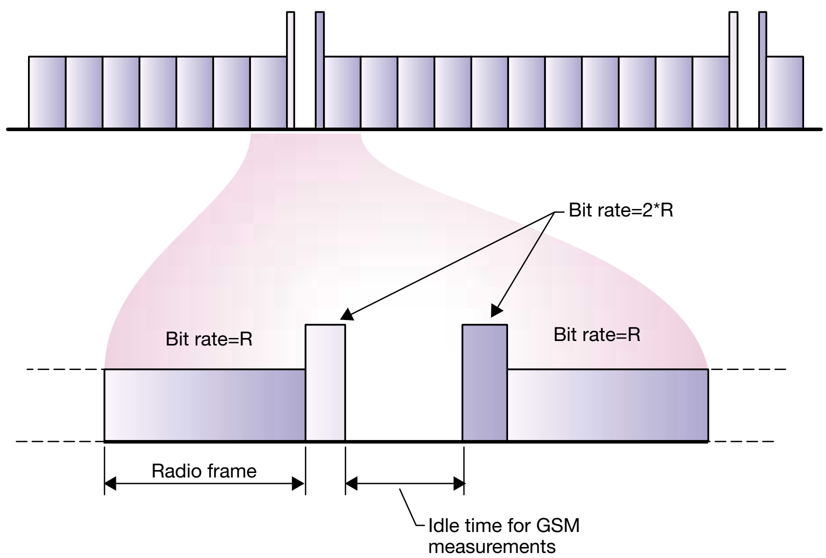
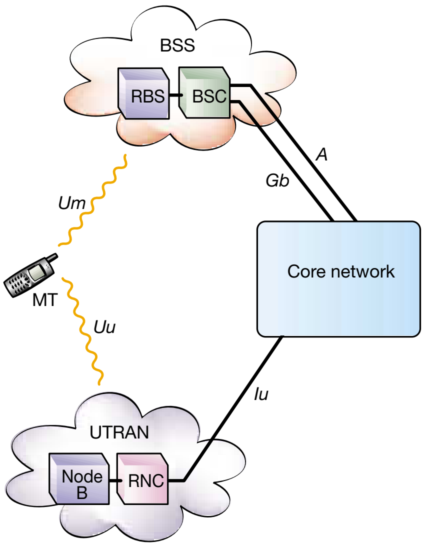


Figure 3
Interoperability of mobile terminals and network equipment from different vendors is crucial for handover between WCDMA and GSM. Ericsson network equipment, in commercial operation in Japan since 2002 (here represented by the Indoor Macro RBS 3202), has been publicly shown (at 3GSM World Congress in Cannes, February 18-21) to interoperate in WCDMA with all major mobile terminal vendors—here represented by two Sony Ericsson Z1010 terminals.

Figure 4
Overview of the GSM and WCDMA nodes and interfaces involved in the cell re-selection and handover procedures.



As mentioned above, a mobile terminal in WCDMA makes use of compressed mode to measure GSM. That is, if the mobile terminal has a single radio receiver, it requires compressed mode. If, on the other hand, the mobile terminal contains separate WCDMA and GSM radio receivers, it can use each receiver in parallel, performing GSM measurements without compressed mode in the downlink. Notwithstanding, each solution—compressed mode and dual receivers—reduces talk time due to higher power consumption in the terminal.

In idle mode, standby time of the mobile terminal is mainly affected by how often it needs to wake up to monitor radio channels and perform measurements for cell re-selection. Since a dual-mode terminal must measure WCDMA and GSM cells, this has a negative effect on standby time compared to GSM-only mobile terminals. To improve standby time, the mobile terminal is allowed to inhibit measurements on the other access technology (for example, WCDMA when in GSM) when the quality of the current access technology is adequate for the network settings. Furthermore, compared to re-selection between GSM cells, the measurement requirements in the standard are more relaxed for re-selection between WCDMA and GSM cells.

Mobility procedures for interworking between WCDMA and GSM

There are two basic modes of operation for handling mobility:

- the mobile terminal-controlled mode; and
- the network-controlled mode.

In the mobile terminal-controlled mode, the mobile terminal selects the cell to which it will connect. However, the network can broadcast various parameters to influence this process.

In the network-controlled mode, the network explicitly orders the mobile terminal to connect to a specific cell. Ordinarily, the network bases its decisions on measurement information provided by the mobile terminal. For either mode of operation, the network should consider cells that use each access technology. Besides radio link quality, the network might also consider other aspects when selecting the cell, for example, the current load of the established service.

Two procedures have been defined by which the network can order the mobile terminal to connect to a cell using another technology, namely the handover and cell change order procedures. These are employed when the mobile terminal uses a dedicated channel. The handover procedure provides a higher level of service, since it involves a preparation phase in which resources in the target cell are reserved prior to the actual handover. Accordingly, the handover procedure is employed when the mobile terminal is providing circuit-switched service—for instance, voice. The cell change order procedure applies when the mobile terminal is providing packet-switched service, such as Web browsing.

Cell re-selection between WCDMA and GSM

While in WCDMA, the mobile terminal performs cell re-selection

- in idle mode; and
- in connected mode when common channels are used for packet-switched service.

The dual-mode mobile terminal re-selects a GSM cell when that cell is ranked higher than the current WCDMA cell or any other WCDMA cell. WCDMA and GSM cells are ranked together according to signal strength. This same type of ranking applies in GSM.

When performing cell re-selection in WCDMA, the mobile terminal either measures GSM cells continuously or when the quality of the serving WCDMA cell falls below a given threshold. The mobile terminal is solely allowed to select a new WCDMA or GSM cell when the average received quality and average signal strength exceed a minimum threshold. The minimum-quality threshold (signal-to-noise ratio) ensures that the mobile terminal can receive the information transmitted by the potential target cell. The minimum threshold for signal strength ensures that the network can receive the information for cell re-selection transmitted by the mobile terminal in the target cell. This criterion also takes into account

- the maximum transmit power that the mobile terminal is allowed to use when accessing the cell; and
- the maximum radio frequency (RF) output power that the mobile terminal can transmit.

Frequent re-selections can be avoided with mechanisms such as penalty time and temporary offset. Likewise, mechanisms are defined to keep fast-moving mobile terminals from re-selecting small-sized cells when a large overlay cell has been configured.

The network can configure these options by broadcasting parameters in the WCDMA cell.

When the mobile terminal is actively providing packet-switched data service in a WCDMA cell and re-selects a GSM cell, it establishes the radio connection to the GSM base station subsystem (BSS) and then initiates the routing area update procedure. During this procedure, the core network may retrieve information from the UMTS terrestrial radio access network (UTRAN) on the context of the mobile terminal, which includes any data packets waiting in the downlink queue. When complete, the connection to UTRAN is released. Finally, the core network confirms the routing area update. Figure 5 shows the message sequence after cell re-selection from WCDMA to a GSM cell in idle mode.

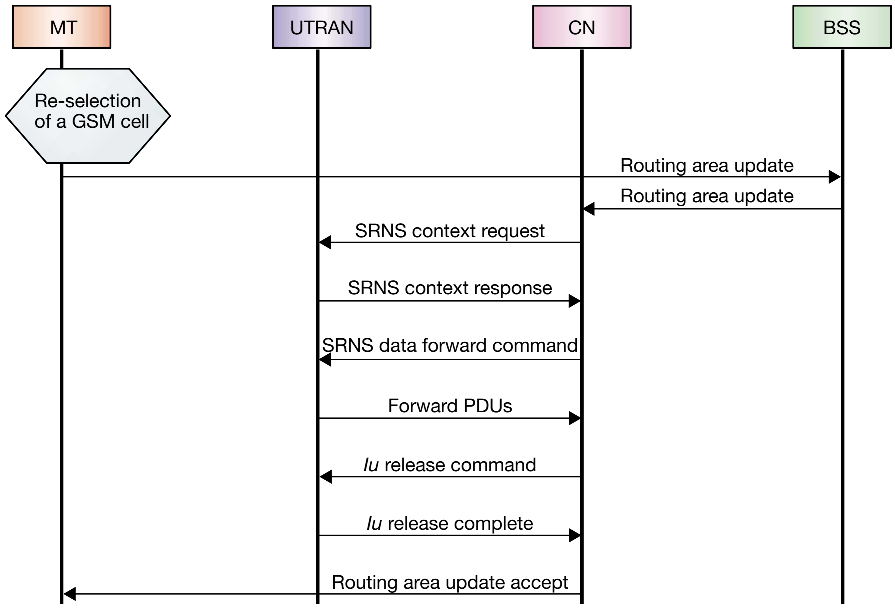


Figure 5
WCDMA-to-GSM cell re-selection.

WCDMA-to-GSM cell change order

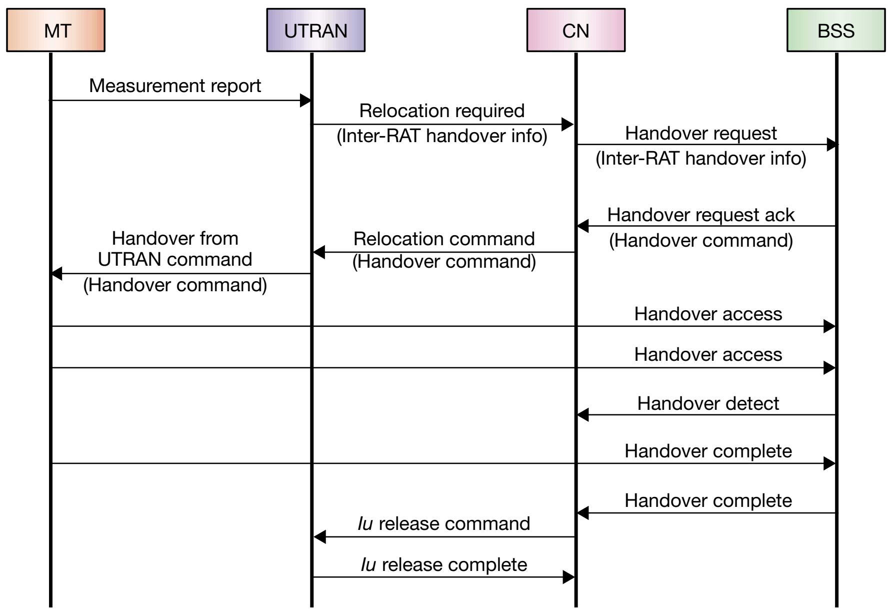
The mobile terminal measures GSM cells and sends measurement reports to the network, which orders the mobile terminal to switch to GSM. The measurement procedure and the use of compressed mode are identical to that described below for the WCDMA-to-GSM handover procedure.

The signaling in the cell-change-order procedure is identical to that in the cell re-selection procedure described in Figure 5 except that the network selects the target GSM cell and initiates the procedure by sending a cell-change-order from the UTRAN message. This message includes the information on the target GSM cell.

Handover from WCDMA to GSM

Figure 6 shows the message sequence for handover from WCDMA to GSM. When the mobile terminal has a circuit-switched service and the signal strength falls below a given threshold, the WCDMA network orders the mobile terminal to perform GSM measurements. Typically, the mobile terminal is instructed to send a measurement

Figure 6
Handover from WCDMA to GSM.



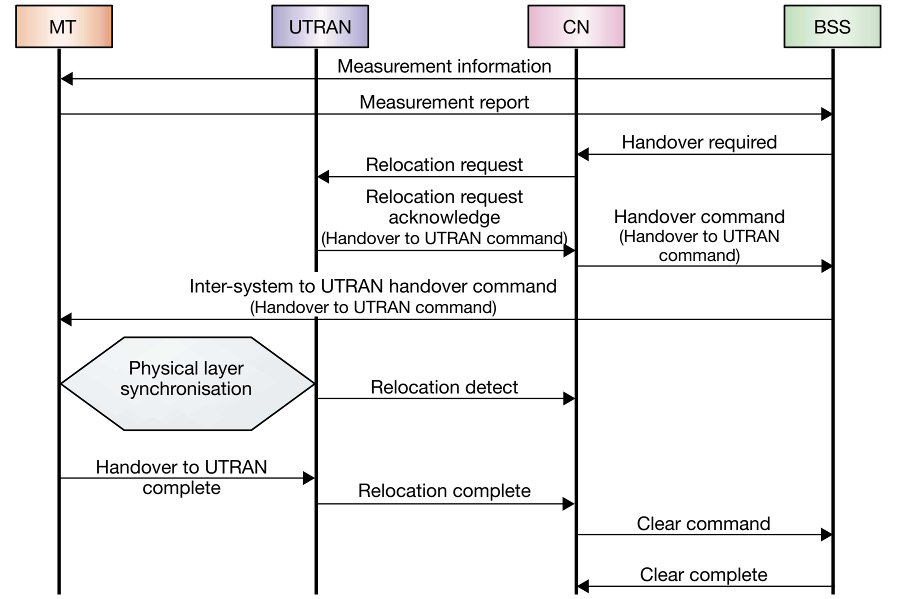
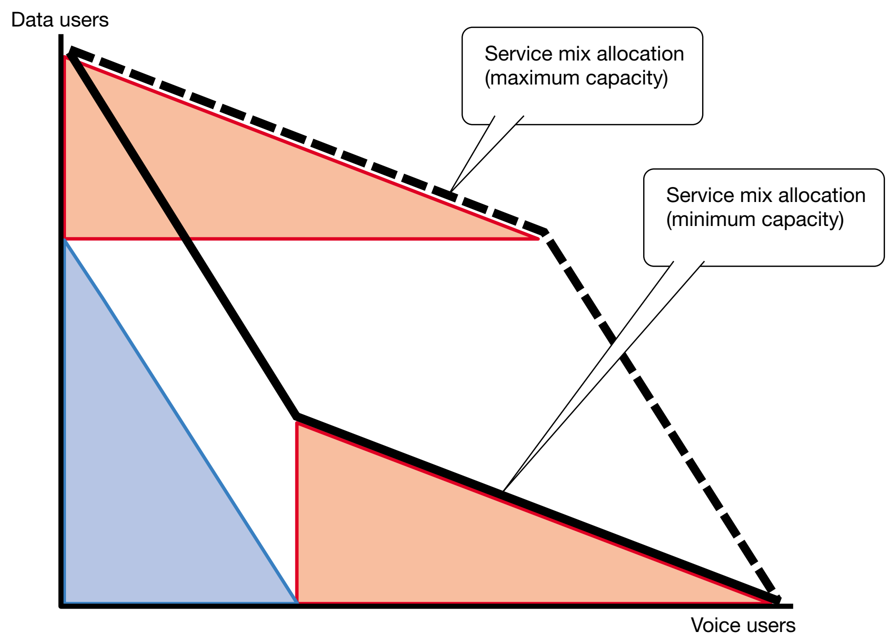


Figure 7
Handover from GSM to WCDMA.

Figure 8
System capacity can be increased by selecting service-based radio access technology. The blue and red triangles describe system capacity to handle voice and data traffic in two separate access technologies, *blue* and *red*. If we combine these technologies and enable service-based handover between them, the capacity can vary depending on how the service is allocated. To achieve maximum capacity, all data users should be allocated to the *blue* technology and all voice users to the *red* (dashed black line). Minimum capacity will result if all data users are allocated to the *red* technology and all voice users to the *blue* (solid black line).



report when the quality of a neighboring GSM cell exceeds a given threshold and the quality from WCDMA is unsatisfactory.

When UTRAN receives the measurement report message, it initiates the handover, given that all the criteria for handover have been fulfilled—for example, provided the mobile terminal is not involved in services that require WCDMA. UTRAN then asks the target BSS to reserve resources. The target BSS prepares a handover command message, which includes the details of the allocated resources. This GSM message, which is sent to the mobile terminal via the WCDMA radio interface, is transferred within a container that is transparently passed on by the different network nodes.

When the mobile terminal receives the handover command, it moves to the target GSM cell and establishes the radio connection in accordance with the parameters included in the handover command message. The mobile terminal indicates successful completion of the handover by sending a handover complete message to the BSS, after which the GSM network initiates the release of the WCDMA radio connection.

Handover from GSM to WCDMA

Figure 7 shows the message sequence for handover from GSM to WCDMA. The network orders the dual-mode mobile terminal to perform WCDMA measurements by sending the measurement information message, which contains information on neighboring WCDMA cells and the criteria for performing and reporting measurements.

When the criteria for handover to WCDMA have been met, the BSS initiates the allocation of resources to the WCDMA cell. Encapsulated in these messages, the BSS also sends information to UTRAN on the WCDMA capabilities of the mobile terminal.

When the resources of the WCDMA target cell have been allocated, UTRAN compiles the handover-to-UTRAN-command message, which typically includes the identity of the pre-defined configuration for the service in use. This message is then sent transparently to the mobile terminal through the core network and BSS.

When the mobile terminal receives the handover-to-UTRAN command message it tunes to the WCDMA frequency and begins radio synchronization. The mobile terminal then indicates that the handover was successful by sending the handover-to-UTRAN-complete message, after which the resources in GSM are released.

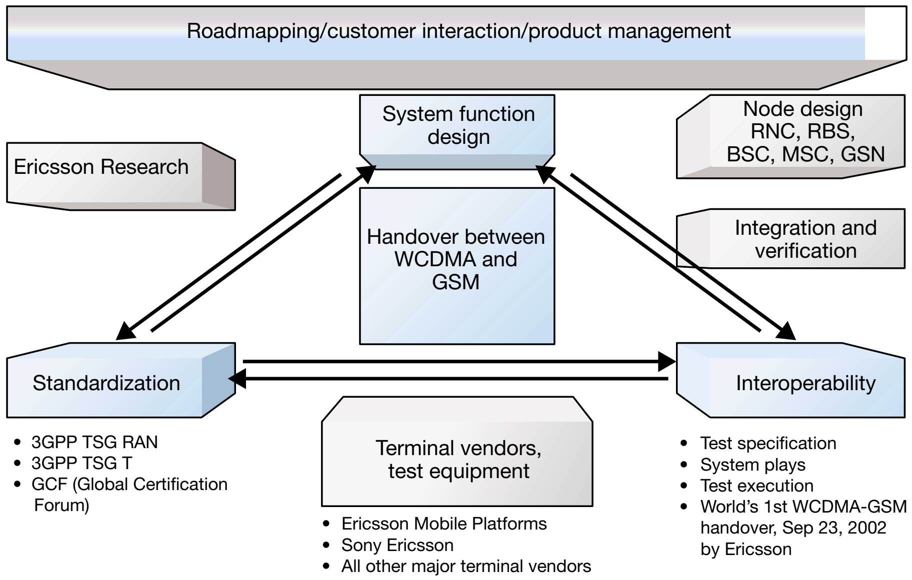


Figure 9
Successful handover between WCDMA and GSM requires a holistic perspective.

From coverage fallback to network optimization

As described above, the first WCDMA commercial networks provide basic coverage fallback to GSM. This fallback is merely the first step on the way toward a true seamless network[2], where WCDMA and GSM, together with other access technologies, combine to form a single network.

There are two important areas in this evolution. The first relates to minimizing the perceived impact on the user when the mobile terminal changes between WCDMA and GSM. The Third-generation Partnership Project (3GPP) is currently working on enhancements to the WCDMA and GSM standards (such as inter-system packet handover) that will reduce the actual interruption in user data transfer from seconds to fractions of a second during packet-switched service.

The other area relates to the ability of the system to select the access technology that is best capable of providing the requested service and quality. This includes the trigger criteria for moving between GSM and WCDMA access technologies. By triggering a change of radio access technology on, for example, the requested service type, it is possible to provide the appropriate quality of service for the call, and to increase the overall capacity of the system. Figure 8 shows the increase in system capacity that can be obtained, provided the system—on the basis of requested services—can allocate traffic on access technologies.

Conclusion

Thanks to interworking between WCDMA and GSM, users of third-generation mobile terminals can enjoy seamless coverage from the very start. The challenges of interworking between WCDMA and GSM have been overcome using

- dual-mode mobile terminals;
- compressed mode channel measurements;
- cell re-selection between WCDMA and GSM;
- WCDMA-to-GSM cell change order; and
- handover between WCDMA and GSM.

Ericsson has successfully demonstrated handover between WCDMA and GSM using dual-mode mobile terminals in a live network. This event, which required a holistic perspective, was the result of a long-term effort (ten years) in research, standardization, system development and interoperability testing.

Ericsson is also a total system provider in the area of WCDMA-to-GSM interworking. The set of features described in this article, such as compressed mode and handover from WCDMA to GSM, is available in the Ericsson WCDMA and GSM network infrastructure and in the mobile terminal platform products being commercially launched in 2003.

REFERENCES

1 Birkedal, A., Corbett, E., Jamal, K. and Woodfield, K.: Experiences of operating a pre-commercial WCDMA network. Ericsson Review Vol. 79(2002): 2, pp. 50-61.
2 Heickerö, R. Jelvin, S. and Josefsson, B.: Ericsson seamless network. Ericsson Review Vol. 79(2002):2, pp.76-83.
3 Hedberg, T. and Parkvall, S.: Evolving WCDMA. Ericsson Review Vol. 78(2001):3, pp. 124-131.
4 Almers, P., Birkedal, A., Seungtai, K. Lundqvist, A. and Milén, A.: Experiences of the live WCDMA network in Stockholm, Sweden. Ericsson Review Vol. 77(2000):4, pp. 204-215.