WCDMA evaluation system—Evaluating the radio access technology of third-generation systems

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The aim of UMTS/IMT-2000 standardization is to produce a truly global standard for third-generation mobile systems. Ericsson's WCDMA evaluation system facilitates UMTS/IMT-2000 standardization, by allowing operators and engineers to demonstrate and test third-generation services and technical solutions. It also enables them to learn about and evaluate WCDMA characteristics in ATM environments.

Ericsson developed the WCDMA evaluation system to demonstrate the potential of the third-generation system, to obtain valuable field experience and input for current commercial development, and to pave the way for the evolution of second-generation systems into UMTS.

The authors describe Ericsson's WCDMA evaluation system, the technical details of the system, its background, and the wide range of end-user services it offers.

Introduction

Ericsson is fully committed to UMTS/IMT-2000 standardization, the aim of which is to produce a truly global standard for third-generation mobile systems. Ericsson's wideband code-division multiple access (WCDMA) evaluation system facilitates UMTS/IMT-2000 standardization, by allowing operators and engineers to demonstrate and test new, advanced, third-generation services and technical solutions. It also enables them to learn about and evaluate WCDMA characteristics in asynchronous transfer mode (ATM) environments. Ericsson developed the evaluation system

- to demonstrate the potential of the third-generation (WCDMA) system;
- to boost intercontinental standardization processes;
- to provide technical input to proposed new standards; and
- to obtain valuable field experience and input for current commercial development;
- to pave the way for the evolution of second-generation systems into UMTS.

With the WCDMA evaluation system, Ericsson has taken WCDMA technology out of the laboratory and put it to test in real radio environments. Thus, Ericsson is now poised to exploit and evaluate the WCDMA-related technology of third-generation radio-access systems.

Background

Late in the year 1996, Ericsson received an invitation to tender from NTT DoCoMo—one of the world's largest mobile phone operators—requesting that Ericsson build a WCDMA evaluation system. At the time, however, a standard for WCDMA as a radio-access technology did not exist. In 1997, the Japanese standardization body, the Association of Radio Industries and Broadcasting (ARIB), began drafting a standard for WCDMA (this first standard was chiefly based on input from NTT DoCoMo in collaboration with Ericsson).

Ericsson agreed to deliver a test system based on early proposals to the ARIB standard. The standard has since matured and has been harmonized with the European standard from the European Telecommunications Standards Institute (ETSI). The detail standardization work continues and is currently being conducted within the framework of the Third-generation Partnership Project (3GPP).

Work on the system began in early 1997, and although it is sometimes called an "experimental" system, Ericsson's designers aimed much higher, building what could be termed a pre-commercial system. In fact, the

BOX A, ABBREVIATIONS

3GPP	Third-generation Partnership Project
ACCH	Associated control channel
ARIB	Association of Radio Industries and Broadcasting
ATM	Asynchronous transfer mode
BCCH	Broadcast control channel
BRI	Basic rate interface
BTS	Base transceiver station
CCCH	Common control channel
DC	Direct current
DCCH	Dedicated control channel
DTCH	Dedicated traffic channel
DTX	Discontinuous transmission
E_b/I_0	Bit energy per interference power spectral density
ETSI	European Telecommunications Standards Institute
FACH	Forward access channel
FDD	Frequency division duplex
GPS	Global positioning system
GSM	Global system for mobile phone communications
IETF	Internet Engineering Task Force
IMT-2000	International mobile telecommunication 2000
IPR	Internet protocol router
ISDN	Integrated services digital network
ITU-T	International Telecommunication Union – Telecommunications Standardization Sector
Iu	Denomination used in standardization work to denote the interface between the BTS and RNC
Iub	Denomination used in standardization work to denote the interface between the RNC and MSC
IWF	Interworking function
ksps	Kilosymbols per second
LAN	Local area network
MCPS	Megachip per second
MSC	Mobile services switching center
MS-SIM	Mobile station simulator
PADP	Packet service adaptation
PBX	Private branch exchange
PCH	Paging channel
PRI	Primary rate interface
PSTN	Public switched telephone network
QPSK	Quadrature phase-shift keying
RACH	Random access channel
RFC	Request for comments
RL-ID	Radio link Identity
RNC	Radio network controller
SDCCH	Stand-alone dedicated control channel
SSCOP'	Service-specific connection oriented protocol' (A cellular system adaptation of the SSCOP. Used in the evaluation system.)
TCH	Traffic channel
TCP/IP	Transmission control protocol/ Internet protocol
UADP	UDI service adaptation
UDI	Unrestricted digital information
UER	Unit error rate
UMTS	Universal mobile telecommunications system
UPCH	User packet data channel
WBTB	Wideband test bed
WCDMA	Wideband code division multiple access
WOS	WCDMA operations system

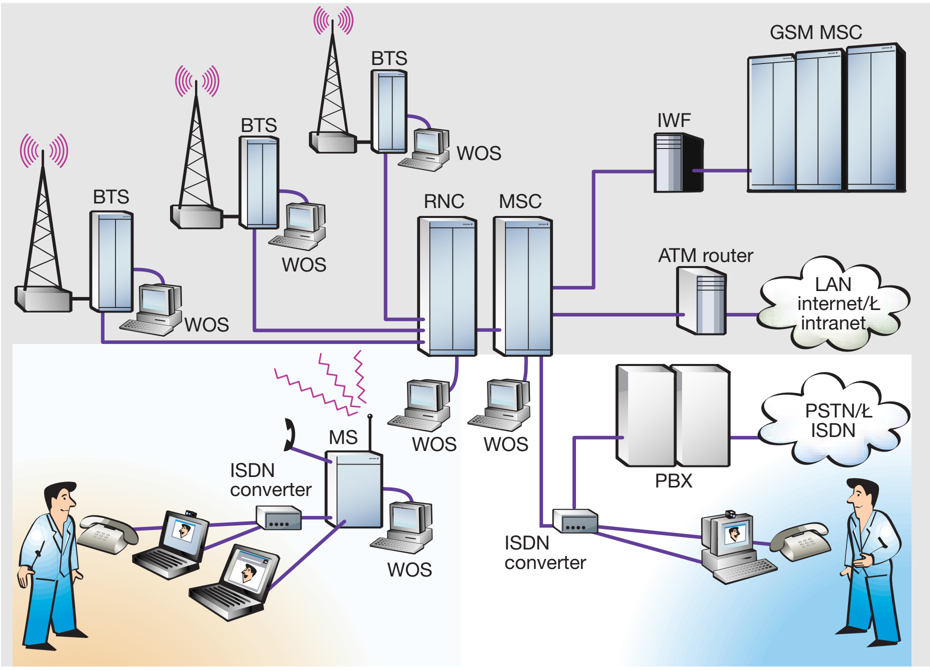

Figure 1
System overview of Ericsson's WCDMA evaluation system.

WCDMA evaluation system has been in small-scale serial production, with close to 30 systems produced to date.

System overview

The WCDMA evaluation system (Figure 1) consists of

- the mobile station simulator (MS-SIM)—note: mobile stations are also sometimes referred to as mobile terminals;
- the base transceiver station (BTS);
- the radio network controller (RNC);
- the mobile services switching center (MSC); and
- the WCDMA operations system (WOS).

The system was built for experimenting with the WCDMA radio-access network and ATM, and for applying these technologies to different wideband services. Consequently, the architecture of the MS-SIM, BTS, RNC, MSC and the WCDMA operations system is very general and flexible.

User data and control information between the RNC and BTS are transported via a preliminary "Iub" interface based on ATM technology ("Iub" is the denomination used in standardization work for the interface between the BTS and the RNC).

Similarly, a preliminary "Iu" interface—also based on ATM transport technology—is used between the RNC and MSC.

To a great extent, the WCDMA part of the evaluation system is based on previous work conducted at Ericsson research centers, including the wideband test bed (WBTB, 1995). The ATM part of the system is built on top of Ericsson's new ATM based development platform, Cello, which was designed specifically to give good cost/performance ATM switching and transport in cellular systems.[1]

Obviously, measurement capabilities are essential in an evaluation system. Measurement data is thus collected from appropriate parts of the system and sent to the WCDMA operations system for logging. The data can then be post-processed for presentation.

Two identical WCDMA evaluation systems have been set up in Stockholm, one of which is mainly used for evaluation purposes; the other is used solely for demonstrations.

Although not actually part of the WCDMA system, a global positioning system (GPS) is used in the evaluation system to provide different nodes with accurate time stamps, so that measurement data from the nodes can be correlated. The GPS also

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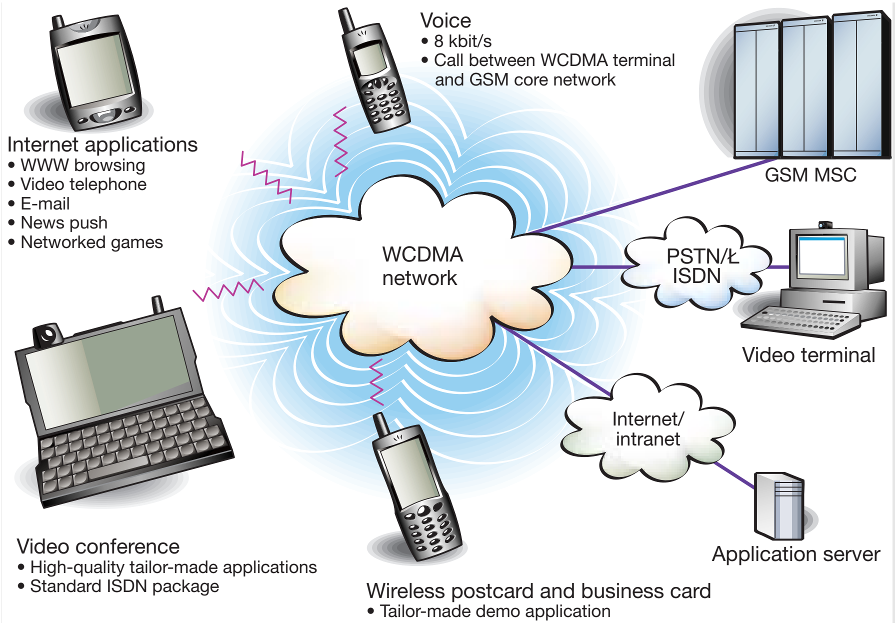


Figure 2
End-user applications in the evaluation system.

TABLE 1, COOPERATING PARTNERS

Partners cooperating with Ericsson to test third-generation wireless capabilities

Market	Partner
Canada	Microcell (GSM Alliance)
China	Third-generation R&D cooperation with China Academy of Telecommunications Technology
Germany	Mannesmann Mobilfunk and T-Mobil
Italy	Telecom Italia Mobile
Japan	Japan Telecom NTT DoCoMo
UK	Testbed open to all UK-based operators
Hong Kong	SmarTone
Sweden	Telia

provides positioning data that can be used for monitoring the whereabouts of mobile stations.

End-user applications

Third-generation mobile telephony systems will offer end-users a wide variety of applications, such as high-speed multimedia services and other services currently only available from fixed networks. Ericsson's WCDMA evaluation system enables operators to evaluate and demonstrate third-generation services.

It is difficult to predict what will happen next as the telecommunications, computer and entertainment industries converge. As mentioned, above, the WCDMA evaluation system was developed to meet the demands of wireless communication in a true multimedia environment. The system has been developed independently of third-generation end-user applications, providing a wide range of bearer services that permit different end-user applications to be evaluated (Figure 2).

Voice and audio

Certainly, standard voice services currently available in second-generation systems must also function in third-generation systems. The WCDMA evaluation system is thus equipped with 8.8 kbit/s voice codecs (G.729). It also provides a means of evaluating and demonstrating interconnection to existing GSM networks.

Video conferencing

Video conference or video phone applications based on circuit-switched connections (such as ISDN) or packet-switched media (such as TCP/IP) are being tested—for example, Microsoft Netmeeting or Intel Proshare-based products. Other video applications like remote monitoring are also possible.

Still- and moving-picture codecs are being tested on the WCDMA evaluation system.

Internet applications

The WCDMA evaluation system supports best-effort packet-switched data up to approximately 470 kbit/s. Access to the Internet and corporate intranets is essential to professional mobile users.

"Push applications" (such as PointCast) are becoming increasingly popular on the Internet, allowing users to subscribe to specific kinds of information; for example, weather forecasts, advertisements, news, company bulletins, and updates of company data, such as price lists. These applications usually entail a background type of traffic; that is, the information reaches the user even when he or she is occupied with other applications. Packet-switched services in the evaluation system support background traffic. A mobile terminal can be logged onto a server and only pay for updated information sent out and not for the connection time.

Corporate LAN access

Today, many people remotely access file servers, databases, and groupware applications on their company LAN. For good performance, high-speed connections must be offered that are at least as fast as landline modems operating at 56 kbit/s.

When working remotely, corporate users want to be "on-line" with their company system; for instance, to see when they receive e-mail. Since cellular calls currently cost more than landline calls, subscribers cannot afford to remain connected eight hours a day. Instead, they must dial in several times a day to check their mail. With WCDMA packet-switched services, however, it will be possible to charge subscribers for volume of data transferred instead of for the duration of the session.

Wireless postcard and electronic business cards

E-mail has become one of the most common mobile data applications on cellular networks. E-mail often includes more than plain-text messages, however. Many messages also carry attachments of additional files—for instance, files of images and video clips. E-mail of this kind requires greater transmission speeds than the present 9.6 kbit/s.

Electronic business cards are currently being standardized—in addition to name, title, company address, and so on, they may include images and other information. Thus, in the future, instead of seeing the number of a caller, his or her photograph might be displayed on the WCDMA mobile terminal (which also doubles as a digital camera).

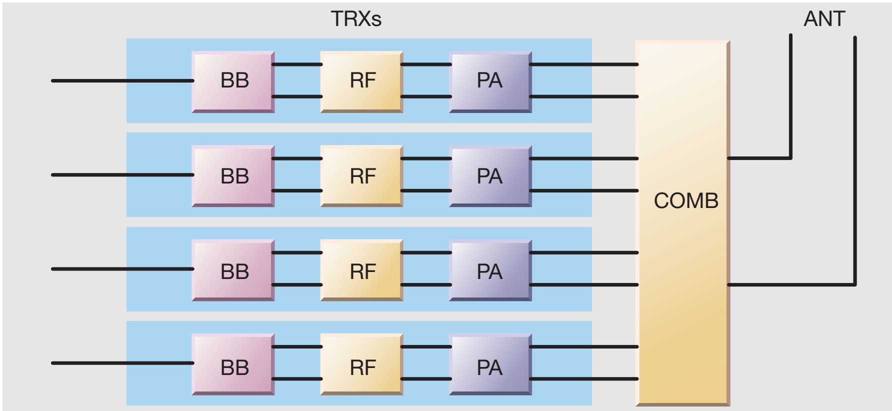


Figure 3
Architecture of first- and second-generation base transceiver stations.
BB Baseband
PA Power amplifier
RF Radio frequency

Other applications

Different user groups have different needs as relates to mobile multimedia. For example, the health sector is investigating interactive health and medical applications (telemedicine); the security sector is interested in remote monitoring; and the traffic sector works with traffic telematics and navigation equipment in vehicles. Furthermore, fire brigades and broadcasting companies could benefit from WCDMA systems to assess situations as the first fireman or journalist comes on the scene.

Intelligent living involves video-on-demand, on-line entertainment applications, and applications that support working and shopping from home. These areas will also require mobile applications.

Worldwide deployment

Following NTT DoCoMo's request for a WCDMA evaluation system, Ericsson received several other queries from operators around the world (Table 1). Ericsson wanted to make the evaluation system available to as many operators as possible. In the United Kingdom, for example, Ericsson operates a test system that is open to all operators—today, every major UK-based operator is working with Ericsson and several new operators have also shown interest.

System architecture

Base transceiver station

To handle mixed services, the base transceiver station in third-generation systems must have a flexible architecture. To meet the requirements for flexibility, designers structured the hardware architecture according to function. That is, instead of using a channel-based architecture, as was done in first- and second-generation systems (Figure 3),the BTS in Ericsson's WCDMA evaluation system uses a pooled architecture. This solution provides greater flexibility for coping with the varied demands of future services (Figure 4).

Figure 4
Architecture of the third-generation base transceiver station.
MCPA Multiple carrier power amplifier

The antennas, which are passive units for transmission and reception, do not require a direct current (DC) power supply. Two identical antennas are used in each sector: one is used for both transmission and reception; the other is solely used for reception. Instead of two antennas in each sector, a dual-polarized antenna can be used, thereby reducing the number of antennas to one per sector. The antenna for each macrocell sector has a mechanical tilt and a fixed electrical tilt.

The architecture of the base station permits the bearer capacity to be freely allocated to users of different types of service:

- voice service;
- circuit-data service carried as unrestricted digital information (UDI) up to 384 kbit/s;
- raw packet-data service up to 472 kbit/s (packet throughput capacity is dependent on radio interference, and consequently, on the SSCOP[1] retransmission rate).

Limiting factors of the total user data bandwidth are the data capacity of the mobile station, the radio cell size, and radio interference.

Radio network controller

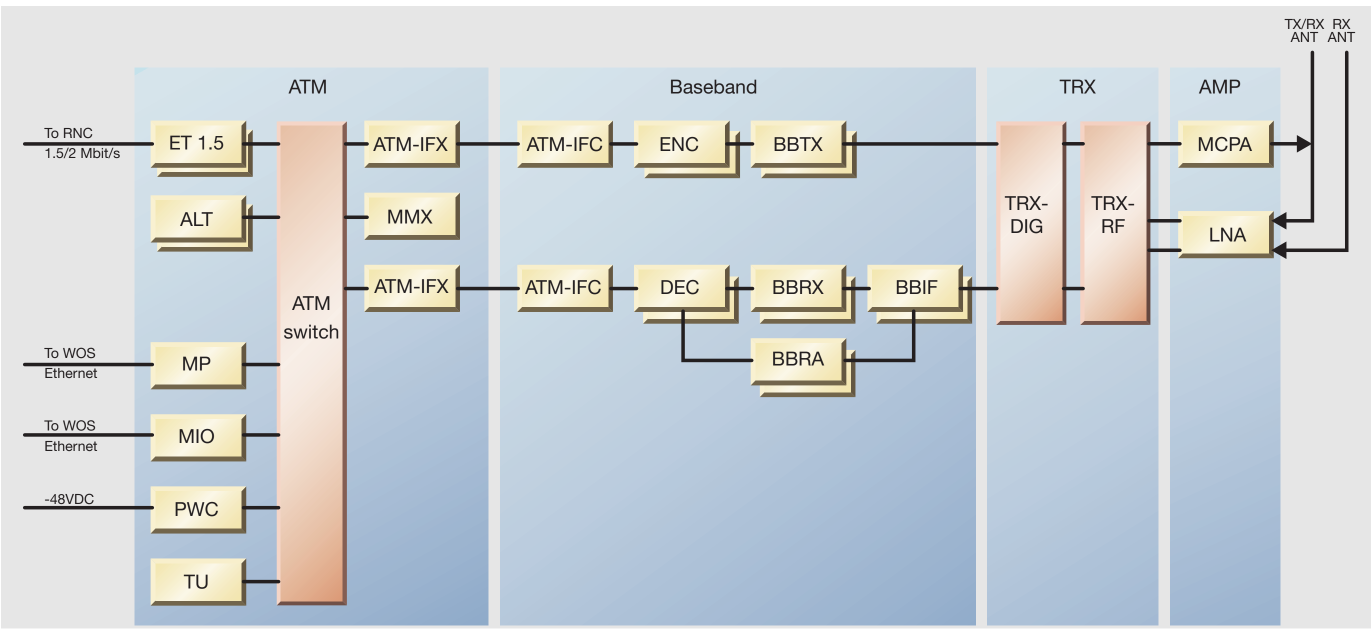
The RNC (which in GSM terminology corresponds to the BSC) is built on Ericsson's generic ATM infrastructure. The processor and all other devices are connected to the ATM switch, which makes it very easy to extend system capacity. The RNC houses

- the radio resource and macro diversity-combination function (also referred to as the soft handover combination function);
- the speech coding/decoding function according to ITU-T recommendation G.729 (provided the codecs are located in the RNC);
- the "Iub" transport based on 1.5 or 2 Mbit/s ATM links with ATM adaptation layer 2 (AAL2) link termination;
- the "Iu" interface (carried on a 155 Mbit/s ATM link); and
- timing and synchronization functions.

At least three base stations can be connected to one RNC, each with up to two 1.5 or 2 Mbit/s "Iub" links. The traffic capacity of the example in Figure 6 is approximately 160 mobile stations connected to each other or to the fixed network. Every connection is switched in the MSC.

Figure 5
Architecture of the BTS.

ALT	ATM link termination
ATM-IFC	ATM interface client
ATM-IFX	ATM interface host
BBIF	Baseband interface
BBRA	Baseband random access
BBRX	Baseband receiver
BBTX	Baseband transmitter
DEC	Decoder
ENC	Encoder
ET	Exchange terminal
LNA	Low-noise amplifier
MMX	ATM multiplexor
TRX-DIG	Transceiver, digital part
TRX-RF	Transceiver, radio frequency part



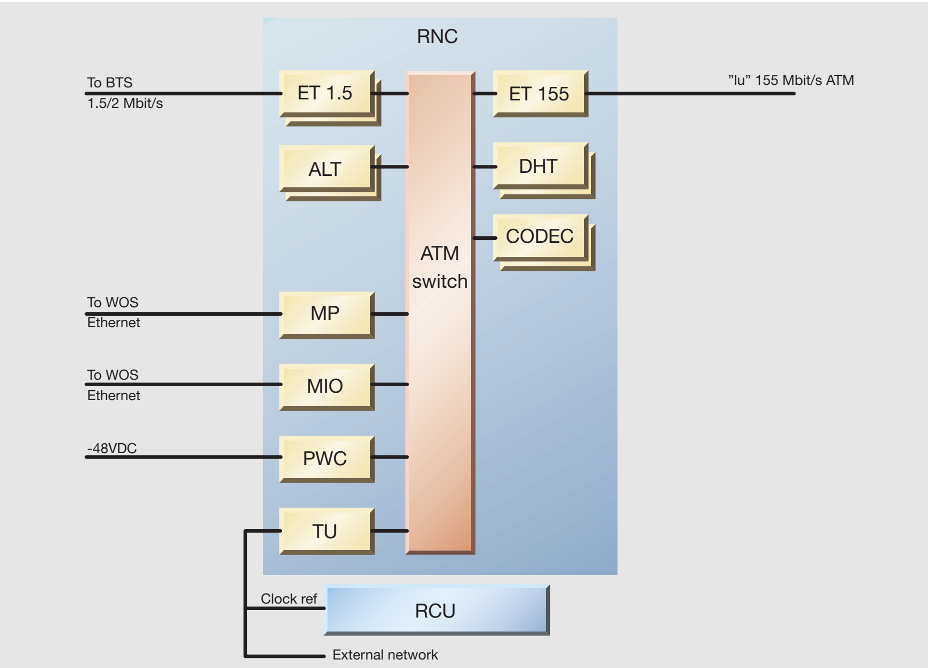


Figure 6
Architecture of the RNC.

PWC	Power connection
RCU	Reference clock unit
MIO	Multi-purpose input/output
MP	Main processor
TU	Timing unit
DHT	Diversity handover

The architecture of the RNC is very flexible, making it ideal for experiments with advanced WCDMA radio-network functions. For instance, to meet new or increased demands, additional printed circuit boards may be installed in empty board positions in RNC subracks. The RNC can also handle large amounts of measurement data in real time, which capability is necessary for experimenting with advanced radio-network functions.

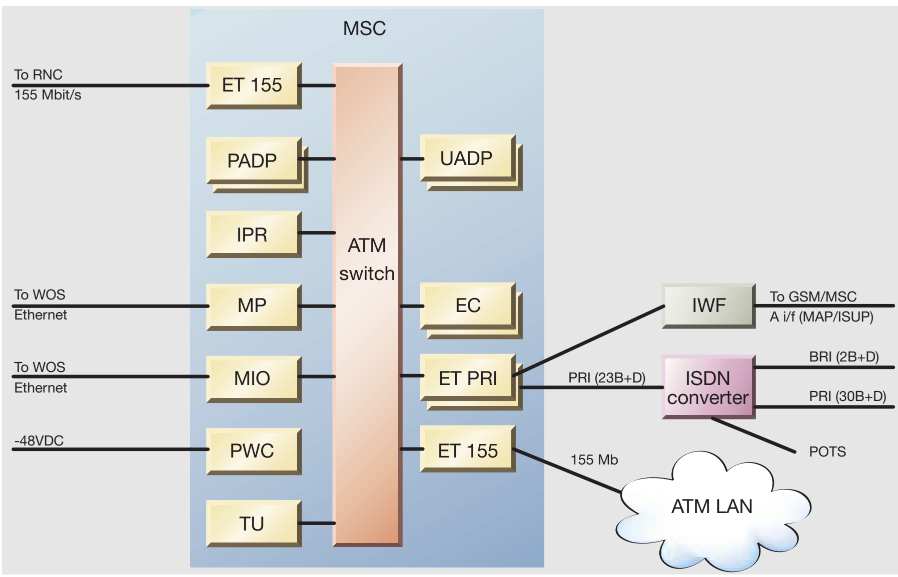
Mobile services switching center

Like the RNC, the MSC is built on Ericsson's generic ATM switch infrastructure and has the same flexible properties as the RNC. Indeed, certain functionality can be moved between the RNC and MSC. The codecs may be put in either the MSC or the RNC—for example, to comply with "Iu" interface standardization, or for other experimental purposes.

The MSC handles the "Iu" interface to the RNC and the fixed network interfaces to ISDN and ATM LAN. The main task of the MSC is to set up calls to and release calls from mobile stations. It includes only a rudimentary level of signaling sequence over the air interface for location updates, authentication, ciphering, and so on. Because it can handle voice as well as circuit-switched and

Figure 7
Architecture of the MSC.

EC	Echo canceller



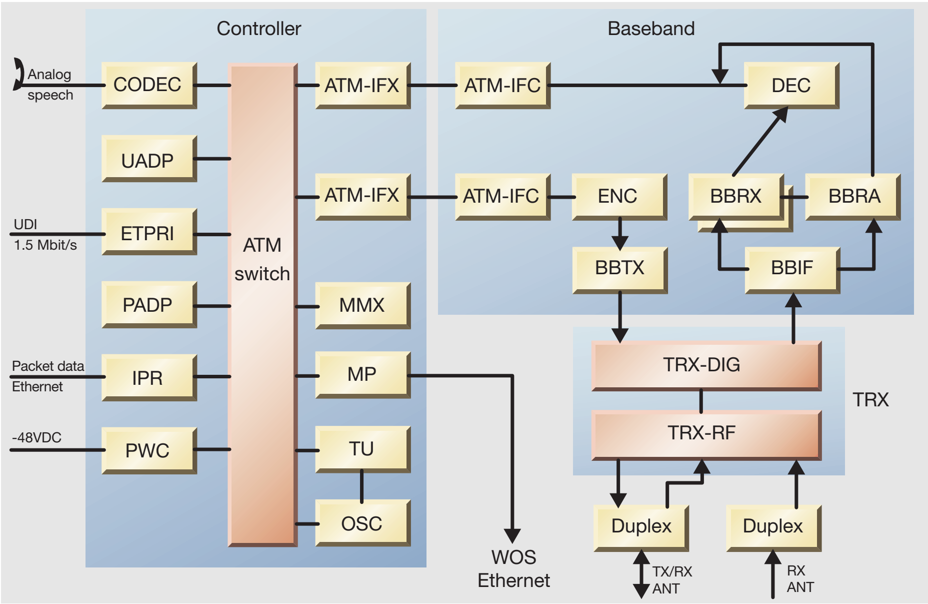


Figure 8
Architecture of the mobile station simulator (MS-SIM).

packet-switched data communication within the same node, the MSC facilitates experimentation with interesting multimedia applications. The MSC includes

- the echo canceller function;
- the IP router;
- the data adapter functions for circuit- and packet-data services;
- ISDN and adapter function interface;
- ATM LAN interface; and
- the speech coding/decoding function according to ITU-T recommendation G.729 (provided the codecs are located in the MSC).

External equipment, such as an ISDN converter, a private branch exchange (PBX) and an ATM router, is used to adapt user data to analog voice, circuit-data and packet-data networks.

The external primary rate interface (ET PRI) complies with the Japanese standards, JT-Q.931 (Layer 3), JT-Q.921 (Layer 2) and JT-I.431a (Layer 1). Moreover, when an external ISDN converter is connected, the European ISDN interfaces (PRI and BRI) can also be provided according to the ITU-T recommendations, Q.931 (Layer 3), Q.921 (Layer 2) and I.430/I.431 (Layer 1). The external ATM LAN uses a permanent virtual circuit (PVC) to carry all IP-over-ATM connections according to the IETF RFC 1483 specification.

Interworking functionality (the IWF unit) in the MSC facilitates connection to a GSM/MSC, which by inserting the GSM subscriber's SIM card into the MS-SIM (SIM-card roaming), enables the MS-SIM to receive voice calls made to a GSM subscriber. The IWF provides a simplified interface according to the GSM A-interface.

The built-in Internet protocol router has the capacity to route IP packets at rates up to 10 Mbit/s. Distribution of capacity between voice, circuit data and packet data can be provided by different configurations of the echo cancellor, UDI service adaptation (UADP), packet service adaptation (PADP), Internet protocol router (IPR) and the PRI.

Mobile station simulator

The MS-SIM was designed exclusively for use in the evaluation system and differs

TABLE 2 TRAFFIC CAPACITY OF A TRIPLE BASE STATION SYSTEM

MS-to-MS calls:
- 80 voice connections;
- 24 UDI connections at 64 kbit/s;
- 3 UDI connections at 384 kbit/s;
- 16 packet connections at 76 kbit/s;
- 3 packet connections at 472 kbit/s; or
- a mix of these services.

MS-to-external calls:
- 16 voice connections and 24 UDI connctions at 64kbit/s; or
- 6 UDI connections at 384 kbit/s over the primary rate interfaces.

MS-to-packet-data services:
- 32 ATM LAN IP connections at 76 kbit/s; or
- 6 connections at 472 kbit/s.

considerably from a commercial unit. It was built drawing on solutions and components for the BTS and design solutions for the RNC/MSC (Figure 8).

ATM Cello

The BTS, RNC, MSC and MS-SIM have been built on the ATM switch platform, which handles internal communication (within each node) as well as communication between nodes and all external connections.[1]

System characteristics

The system operates within the IMT-2000 band and has the following characteristics:

- Operational band—uplink (reverse) 1,920-1,940 MHz; downlink (forward) 2,110-2,130 MHz;
- 190 MHz duplex distance;
- Frequency division duplex (FDD);
- 4,096 Megachips per second (Mcps) chip rate;
- 5 MHz carrier width;
- Modulation/demodulation method
  - for data: QPSK, pilot-aided coherent detection RAKE receiver;
  - for spreading: QPSK;
- Encoding/decoding method
  - innercoding for traffic channels and ACCH;
  - convolutional encoding (R=1/3, K=9), soft-decision *Viterbi decoding*;
  - innercoding for all control channels except ACCH;
  - convolutional encoding (R=1/2, K=9), soft decision *Viterbi decoding*;
  - bit interleaving (all channels);
- Short code, 256 to 32 chip long-layered orthogonal code; and
- Long code
  - downlink, 10 ms (use $2^{16}-1$ chip long *Gold code* cut into 10 ms lengths);
  - uplink, $2^{25} \cdot 10$ ms (use $2^{41}-1$ chip long *Gold code* cut into $2^{25} \cdot 10$ ms lengths).

Every channel in the WCDMA network can be concentrated to a single sector. Conversely, channels can be freely distributed over three sectors and two carriers.

All ATM transport functionality—internally in the BTS and for the "Iub"—is derived from the Ericsson ATM switch infrastructure in the RNC and MSC.

The MSC can handle 16 codecs for a total of 16 fixed-network voice connections.

In each BTS, it is possible to connect traffic capacity corresponding to

- 6 sectors with one 5 MHz carrier; or
- 3 sectors with two 5 MHz carriers per sector.

For circuit-switched transmission it is possible to connect

- 64 voice connections;
- 16 UDI connections at 64 kbit/s; or
- 2 UDI connections at 384 kbit/s.

For packet-switched transmission, it is possible to connect

- 8 packet-switched connections at 76 kbit/s; or
- 2 packet-switched connections at 470 kbit/s.

It is also possible to mix services; for example:

- 16 voice channels;
- 4 UDI connections at 64 kbit/s;
- 2 packet-switched data connections at 76 kbit/s; and
- 1 packet-data connection at 472 kbit/s.

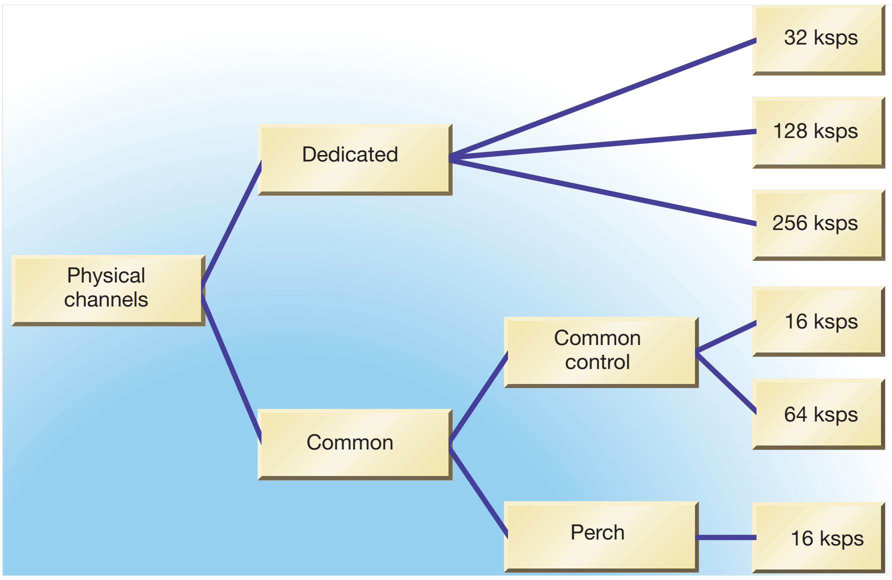


Figure 9
Physical channels.

The air interface

The air interface is based on early versions of what is today being finalized in the 3GPP. The carrier width is 5 MHz. Thus, given the total bandwidth of 20 MHz, there are four selectable frequencies. Each carrier contains several physical channels (Figure 9), each of which is defined by a unique

- long code;

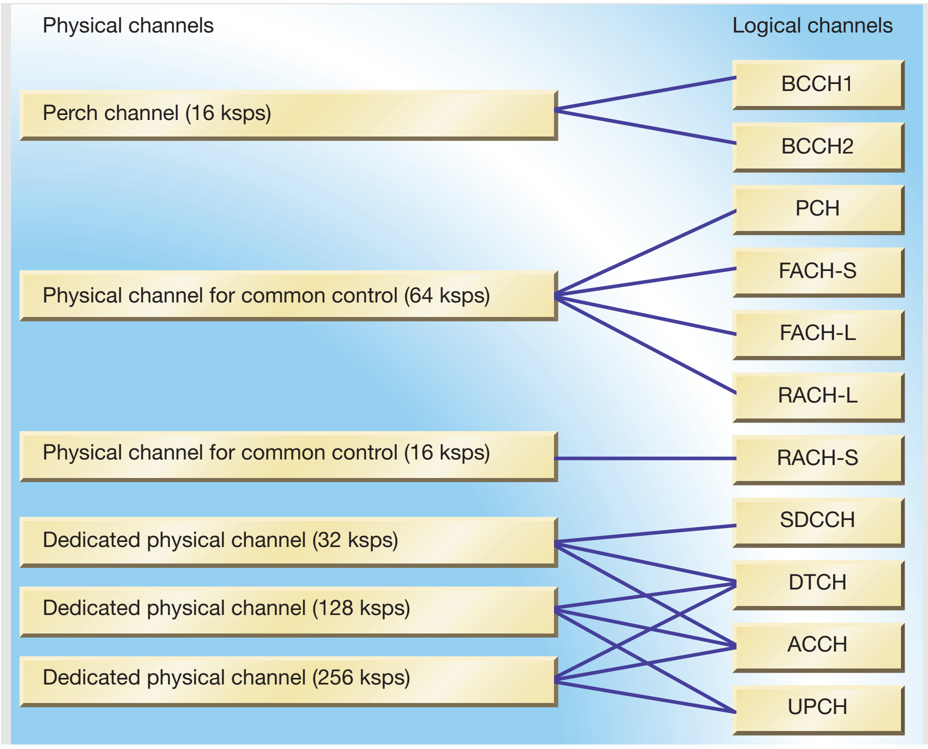


Figure 10
Mapping of logical channels onto physical channels.

- short code; and
- transmission rate.

A variety of information is transmitted between the BTS and the mobile station. Different logical channels are used depending on the type of information being transmitted. Each logical channel is used for a specific purpose, such as paging, call setup and speech transmission. The logical channels are mapped onto the physical channels (Figure 10).

Logical channels

The air interface consists of three kinds of logical channel, namely:
- common control channels (CCCH);
- dedicated control channels (DCCH); and
- traffic channels (TCH).

Common control channels

The *broadcast control channel* (BCCH 1/2) is a unidirectional downlink channel for transmitting system control information on cells or sectors—such as long code phase information, uplink interference power, and so on—from the BTS to the mobile station. This channel transmits system information whose content changes over time. The information is transmitted continuously.

The *paging channel* (PCH) is a unidirectional downlink channel that transfers paging information from the BTS to the mobile station. The same paging information can be transmitted simultaneously via several BTSs as well as to several sectors of each BTS.

Random access channels (RACH-short, RACH-long) are unidirectional uplink channels for receiving initial access requests from mobile stations.

Forward link access channels (FACH-short, FACH-long) are unidirectional downlink channels for transmitting control information and random access acknowledgments from the BTS to a mobile station. The common RACH/FACH channels are also used for transmitting low-speed packet data to and from several mobile stations.

Dedicated control channels

The *stand-alone dedicated control channel* (SDCCH) is a point-to-point bidirectional channel that transfers control information between the mobile station and the RNC. The channel occupies one physical channel. The SDCCH exchanges information on service selection, authentication, and location updates. The SDCCH is only used after ran-

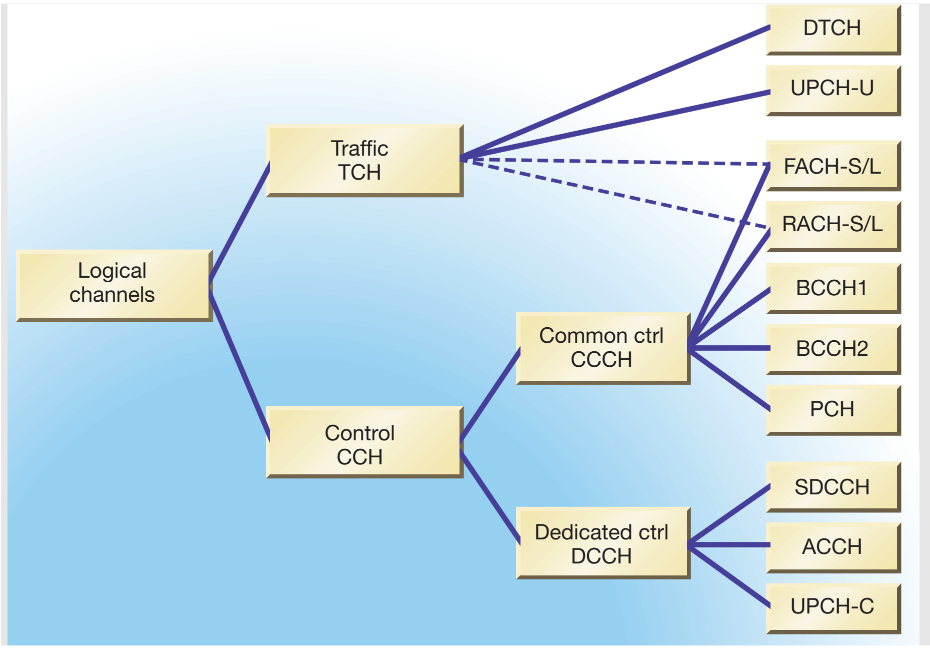


Figure 11
Structure of the logical channels.

dom access. After use, the connection is released.

The *associated control channel* (ACCH) is a point-to-point bidirectional channel that transfers control information between a mobile station and the RNC. This channel is associated with the dedicated traffic channel (with which it is multiplexed on a single physical channel).

Traffic channels

The *dedicated traffic channel* (DTCH) is a point-to-point bidirectional channel that transmits and receives user information. Discontinuous 32 ksps transmission is supported for speech. To support high-speed packet-switched data, the multicode function associates one radio-link identity (RL-ID) with multiple codes of identical symbol rates. (See also Table 3) This is the case when a high-speed service (384 kbit/s) is transmitted on three 256 ksps physical channels—each with a unique code.

The *user packet data channel* (UPCH) is a point-to-point bidirectional channel between the MSC and a mobile station that is used for packet-data services (user packet

TABLE 3 CORRELATION BETWEEN SERVICES, LOGICAL CHANNELS AND PHYSICAL CHANNEL RATE

Service	Information rate	Logical channel	Physical channel rate
Voice	8 kbit/s	DTCH	32 ksps
UDI 64	64 kbit/s	DTCH	128 ksps
UDI 384	384 kbit/s	DTCH	3·256 ksps
Packet 76	76 kbit/s	UPCH	128 ksps
Packet 470	470 kbit/s	UPCH	3·256 ksps

data and control packet data). The multicode function associates one RL-ID with multiple codes of identical symbol rates (valid for 3 · 256 ksps).

Evaluation

Numerous tests can be executed within the Ericsson WCDMA evaluation system. The descriptions that follow highlight the capabilities of the system.

Transmitter and receiver performance

A large battery of tests is used for evaluating transmitter and receiver performance. The tests cover basic performance under "normal" conditions, quantitative tests made in the laboratory using specified channels, and field trials, which are assumed to be slightly more demonstrative of "real-life" characteristics. Some tests may also be performed under extraordinary and rapidly changing conditions (for instance, when a user enters or exits a building). These tests evaluate the robustness of algorithms and the effects of delay in the system.

Detector performance

Detector performance is tested to verify searcher/tracker performance in different environments, to find suitable parameter settings for observed and anticipated multipath environments, and to assess performance during soft handover, where synchronous performance can be closely monitored. The detector performance tests

- verify equipment sensitivity;
- investigate searcher performance in different dispersive environments;
- test tracker performance for known dispersion types;
- verify searcher/tracker performance during soft/softer handover;
- measure E_b/I_0 detectors for different interference types; and
- investigate the effects of using different numbers of rake fingers.

Idle mode

Tests of the idle mode indicate the general characteristic performance of specific algorithms, radio interface and mobile-station hardware implemented in the evaluation system. The tests also assess parameter dependency and the performance of sector selection, including time delay while in idle mode. In particular, the tests examine initial and continuous sector selection in idle mode.

Open-loop performance

Measurements can be made to estimate the extent to which measured data on one link can be used for predicting the accuracy of another link when setting various parameters. The measurements, which can be made in stationary and variable environments, estimate the quality of the open-loop power control for the RACH/FACH and the initial power setting when setting up the CCH. The tests of open loop performance predict:

- power level capability; and
- the consequences of RACH/FACH and the initial CCH power setting.

Random access performance characteristics

Certain tests evaluate the performance of the random-access procedure implemented in the WCDMA evaluation system as well as the effect of different parameter settings of the acquisition procedure. The tests measure the effects of interference levels and the interfering effects that RACH/FACH procedures have on established calls. In particular, the tests

- assess RACH performance in different power-regulation schemes; and
- examine disturbances from RACH/FACH bursts.

Uplink and downlink control

Testers evaluate the performance of the fast uplink/downlink power control loop in terms of speed, stability, performance when E_b/I_0 is low, and operation during soft/softer handover.

The practical performance of the control loop, in terms of its ability to maintain a constant E_b/I_0 value is in variable radio environments, is assessed for estimating the need for reference value control. A special area of interest focuses on performance at cell fringes and, in this context, the effects of soft/softer handover. The effects of sudden environmental changes (turns in the road, outdoor/indoor usage) can also be studied, as well as step responses during handover and resynchronization. The tests also check the effects of low data rates; for instance, due to poor synchronization or when DTX is used. The downlink tests are similar to tests of the uplink power control. The tests of the uplink and downlink power control assess

- response times;
- the effects of simultaneous multiple channel types;
- the influence of different dispersion environments;

- the effects of changing environment;
- the effects of TPC channel quality;
- performance during soft/softer handoff;
- the influence of DTX; and
- the effects of mobile terminal velocity.

Outer loop

The outer loop or quality control loop is used to compensate for changes in statistical properties as well as the effects of imperfect discriminators and processing. The control loop can be verified for different multipath (dispersion) environments and changes between such environments. The tests may also be used for studying how well the outer loop compensates for non-ideal behavior of the fast loops in the uplink and the downlink. The tests of the outer loop assess

- the dynamic range/granularity required for a specific E_b/I_o target;
- single channel performance;
- the effects of changing environment;
- performance during soft/softer handover; and
- the effects of mobile station velocity.

Soft/softer handover

Testers evaluate the performance of different soft/softer handover criteria in real radio environments, including quasi-stationary and rapidly changing radio environments (for example, at street corners and street crossings. They also assess performance as a function of different parameter settings (timers, weights), investigate perch power levels and estimate soft handover gain. The tests of soft/softer handover

- identify critical parameters for sector detection and selection timing;
- assess the effects of different evaluation criteria;
- assess the influence of active set parameters;
- assess the influence of perch power levels and other parameters;
- assess handover gain;
- assess performance during cell breathing; and
- assess synchronization.

Hard handover

Testers evaluate the performance of the system's hard handover function at different parameter settings. In particular, they assess the effects of sector selection and synchronization. The tests of hard handover assess

- the importance of different parameters;
- synchronization;
- hard handover gain; and
- the effects of cell breathing.

Radio switching (packet handover)

Testers evaluate the performance of the system's radio-switching function, particularly during "normal" behavior. The tests of radio switching assess

- the effects of different evaluation criteria;
- reporting intensity;
- quality and parameter sensitivity;
- radio switching setup times;
- street effects; and
- synchronization.

Channel type switching

Testers evaluate the performance of channel type switching when different evaluation criteria and reporting intensities are used. They also study handover quality, which includes the effects of synchronization and the handover procedure. The effects of cell breathing may also be studied, provided a suitable test environment can be generated. Observed traffic behavior can be compared with that of traffic models. The tests of channel type switching assess

- switching intensity/parameter sensitivity;
- quality;
- street effects;
- the relevance of available traffic models;
- differences between coverage of dedicated and common channels; and
- the effects of cell breathing.

Call setup performance

Call setup performance is studied for different services and terminals. Testers study voice, UDI 64 kbit/s and 384 kbit/s as well as packet-data traffic between mobile stations (MS-to-MS) and between mobile stations and the PSTN, ISDN and GSM networks. The tests of call setup performance assess

- the performance of different services; and
- the influence of mobile stations.

ATM transport characteristics

Testers evaluate various aspects and characteristics of ATM transport performance. If the capacity of the transport network far exceeds that of the air interface, system performance is not significantly affected. However, if the capacity of the transport network is on a par with that of the air interface, it will have a noticeable impact on system performance. The main focus of the test cases is on performance, measured as delay and frame loss versus throughput. The tests also

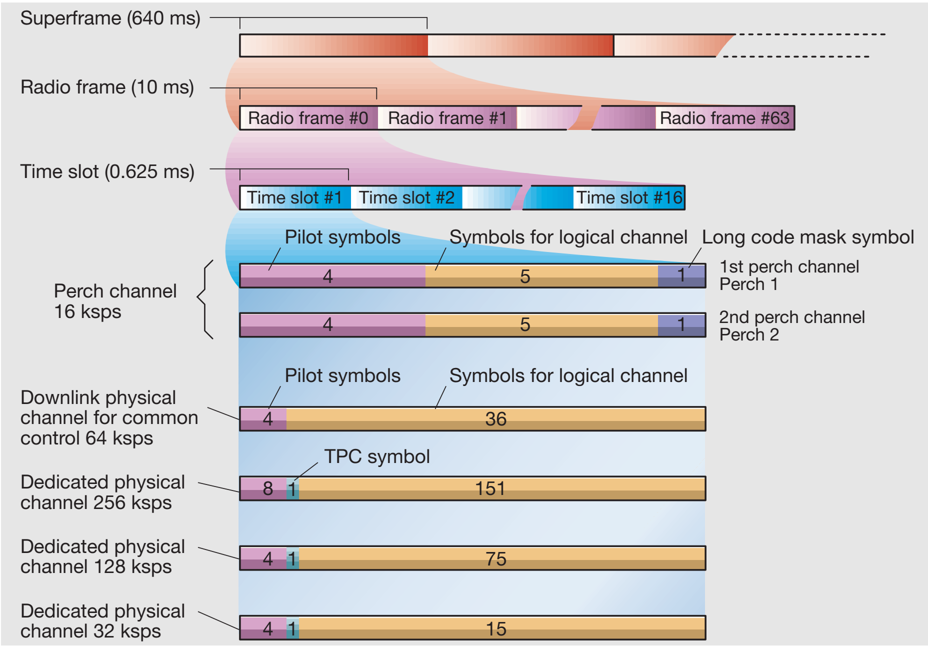


Figure 12
Physical channel format—every physical channel has a three-layer structure that consists of superframes, radio frames and time slots. The structure of the radio frames and time slots varies, depending on the physical channel and symbol rate used.

examine functionality and synchronization. The tests of ATM transport characteristics assess

- the dependence of load on throughput and quality;
- synchronization; and
- statistical multiplexing of packet data and voice, which is used to reduce the demand for transport capacity.

Protocol measurements

Tests of protocol measurements study protocol performance, measured as unit error rate (UER), peer-to-peer delay and rate of retransmission of single protocols, and interactions between different protocol layers. These interactions are particularly interesting as they relate to the study of packet applications that retransmit on many protocol layers. The issues of timing and synchronization, as they relate to the respective system functions, are covered by tests of those functions. The purpose of these test cases is to study the delay, timing, and synchronization properties of the system that are not directly associated with any particular system function. The protocol measurements help testers to assess

- the performance of a single protocol; and
- interaction between different protocols.

End-user application characteristics

Tests of end-user application characteristics are made to study perceived end-user quality. These tests focus on physical measurements, UER, round-trip delay, and so on.

Issues that interest testers include data rate efficiency. For example, are high data-transmission rates significantly better than lower data-transmission rates when channel type switching and its consequences on retransmission on different layers is taken into account relative to the actual duration of the call? Studies of end-user application characteristics

- compare the efficiency of different data rates; and
- assess service quality, including the Web.

Radio network characteristics/radio network planning

Tests of radio-network characteristics and planning help testers to estimate system be-

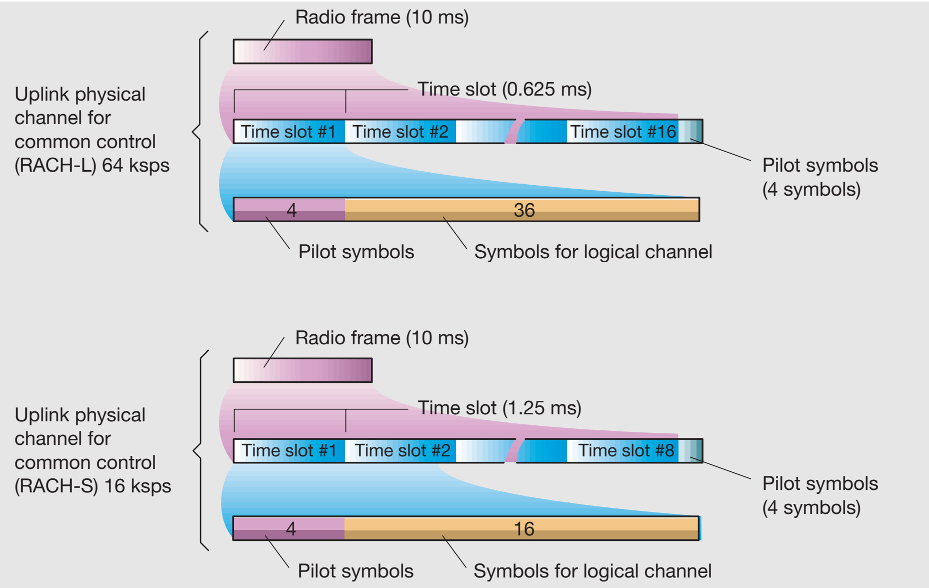


Figure 13
The format of the physical channel for common control differs slightly from that shown in Figure 12, since it handles access (random access and packet data on common channels) for several mobile stations.

havior, including coverage/capacity in different configurations. The tests

- identify stability limits;
- assess near/far effects;
- assess perch power level planning;
- verify orthogonality with mixed channels;
- verify path-loss prediction (half-screen); and
- assess the effects of pulsed interference.

Antenna solutions

Testers evaluate the influence that different antenna types and tilting have on coverage and soft handover. The tests of antenna solutions assess

- the effects of practical antennas; and
- the usefulness of antenna tilting.

Conclusion

Ericsson began testing WCDMA during the early part of 1995. Today, Ericsson operates fully developed WCDMA radio networks in several parts of the world.

The architecture of the MS-SIM, BTS, RNC, MSC and the WCDMA operations system is structured by function and is very flexible.

All ATM transport functionality is derived from the Ericsson ATM switch infrastructure in the RNC and MSC.

The WCDMA evaluation system was built for experimenting with the WCDMA radio-access network and ATM, and for applying these technologies to different wideband services. Thus, operators can use the system to evaluate numerous WCDMA system characteristics including

- transmitter and receiver performance;
- detector performance;
- idle mode performance;
- open loop performance;
- random access performance;
- uplink power control;
- downlink power control;
- soft/softer handover;
- hard handover;
- radio switching (packet handover);
- channel type switching;
- call setup performance;
- ATM transport;
- protocol measurements;
- end-user applications; and
- antenna solutions.

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1 Reinius, J.: Cello—An ATM transport and control platform. Ericsson Review Vol. 76(1999):2, pp. 48–55.