Advanced baseband technology in third-generation radio base stations

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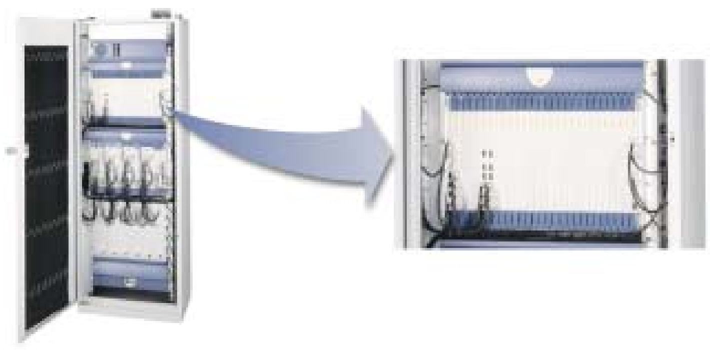
WCDMA, one of the technologies selected for the air interface of the 3GPP standard, is widely used in emerging third-generation mobile communication systems. This interface supports data rates of up to 2 Mbit/s on a common 5 MHz frequency carrier. Moreover, with the introduction of HSDPA, the peak service rate for packet access in the downlink can be increased to more than 10 Mbit/s.

Ericsson's radio base station has been designed to comply with the 3GPP standard. The kernel part of WCDMA technology has been implemented in the baseband of the radio base station. Compared to previous generations, the baseband signals in WCDMA are spread with a high chip-rate code at 3.84 megachips per second on a 5 MHz frequency band. This is much wider than the frequency band used in GSM, cdmaOne and CDMA2000, or PDC. Therefore, to process the signals, more advanced technology is deployed in WCDMA baseband. Ericsson's baseband technology uses the very latest ASIC, DSP, and FPGA technologies.

Numerous requirements are being channeled toward the baseband platform, both to support a technical implementation of WCDMA and to satisfy operator and radio network management points of view. Being the kernel in WCDMA, the baseband platform must be able to efficiently handle the entire life cycle of an RBS, from initial deployment, with a low-cost, low-content focus, to subsequent scaling for newly developed services and traffic growth. Moreover, it must do so while networks are evolving and expanding with more users and new mixes of end-user services. New radio network functions and features will also be added through base station hardware and software to perfect the WCDMA system.

The authors describe the implementation of Ericsson's WCDMA baseband. They also show how it has been prepared to grow with and meet the needs of future developments by facilitating small, incremental upgrades and thanks to a flexible architecture that supports the expansion of the uplink and downlink together with critical functionality that resides in loadable hardware.

Figure 1
Indoor RBS and baseband subrack.



Architecture of the radio base station

The functionality of a radio base station (RBS) is divided into two main parts: user-plane functions and control-plane functions. The user-plane functions are associated with transport, baseband, radio and the antenna. The control-plane functions pertain to the transmission of user data and operation and maintenance (O&M) data. Ericsson's RBS is based on the connectivity packet platform (CPP, formerly called Cello packet platform)—that is, the RBS employs the infrastructure of hardware and software modules provided in CPP.[1]

Figure 1 shows a typical indoor RBS with power subrack, baseband subrack, radio frequency subrack and power amplifier subrack.[2] User-plane signals from the radio network controller (RNC) via the *Iub* interface are input directly via CPP boards to the baseband parts, whereas control-plane signals are input to the baseband parts via the traffic and O&M control parts of the main processor. Figure 2 shows the architecture of the Ericsson RBS3000.[3] Please note that for simplicity's sake the CPP parts and main processor are not shown.

The architecture can be broken down into a cell-specific part and a non-cell-specific part. The cell-specific part contains transceiver (TRX) boards, multicarrier power amplifier (MCPA) boards and antenna interface unit (AIU) boards, whereas the common part contains boards for baseband processing. In Figure 2, the baseband processing has been split between the transmitter (TX) and random access and receiver (RAX) boards. The TX board handles downlink processing and enables coding, spreading and modulation. The RAX board handles uplink processing and enables demodulation, de-spreading and decoding.

Baseband functions

The physical layer functions on the baseband boards have been implemented to include
- the mapping and de-mapping of physical channels and transport channels;
- multiplexing and demultiplexing;
- channel coding and decoding;
- spreading and de-spreading;
- modulation and demodulation;
- physical layer procedures; and
- physical layer measurements.

In addition, the baseband boards in a radio base station perform the following functions:

- radio base station configuration;
- cell control;
- the distribution of system information;
- radio link configuration for dedicated and common channels;
- *Iub* data-stream handling; and
- node synchronization and distribution.

The baseband functions in the radio base station thus provide a platform for radio network functions, configuration functions, and O&M functions. Accordingly, the baseband constitutes a platform of resources for handling common and dedicated channels for higher layers.

Figure 3 gives an overview of standard channel mapping between logical channels, transport channels and physical channels.[4,5] The upper part pertains to the downlink channels and the lower part (shown in dark blue) pertains to the uplink channels. The Third-generation Partnership Project[6] (3GPP) has defined the

- synchronization procedures for cells, common channels and dedicated channels;
- random-access procedures; and
- inner- and outer-loop power control procedures.

To improve the performance of the radio link connection, the 3GPP has recommended possible enhancements, such as open-loop and closed-loop transmit diversity. After the baseband boards have been configured properly with respect to the interfaces to other subsystems, they can be put into traffic operation. If the traffic load on the baseband is light, all or part of the board can be put into power save mode to reduce power consumption. By contrast, supervision and protection mechanisms reduce the risk of dropped calls when the traffic load on the baseband boards is too heavy.

Baseband design aspects

Ericsson's baseband has been designed to comply with 3GPP standards for WCDMA. In addition, the baseband architecture has been designed to meet requirements for operating radio base stations. These include configuration flexibility, effective use of resources, easy roll-out, compatibility and future-proof hardware. By introducing the very latest in digital signal processor (DSP), field-programmable gate array (FPGA) and application-specific integrated circuit (ASIC) technologies, Ericsson has significantly increased the capacity for traffic and

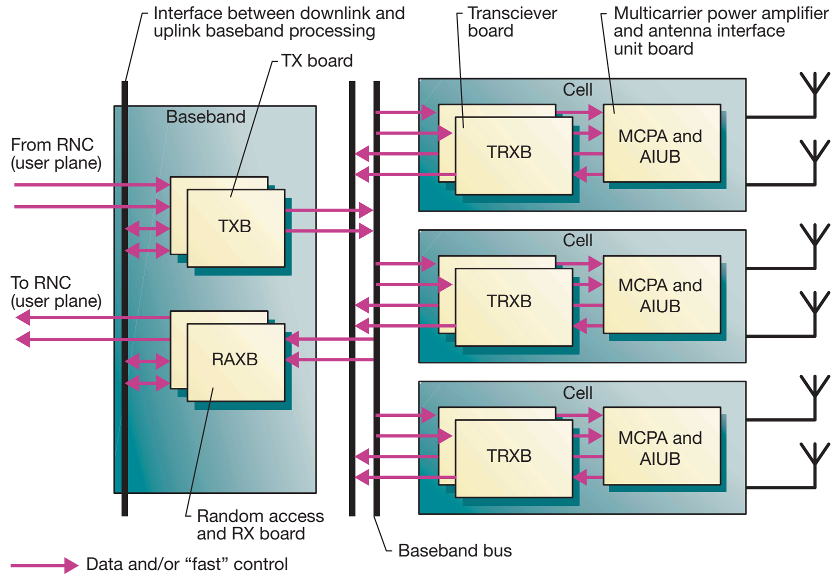
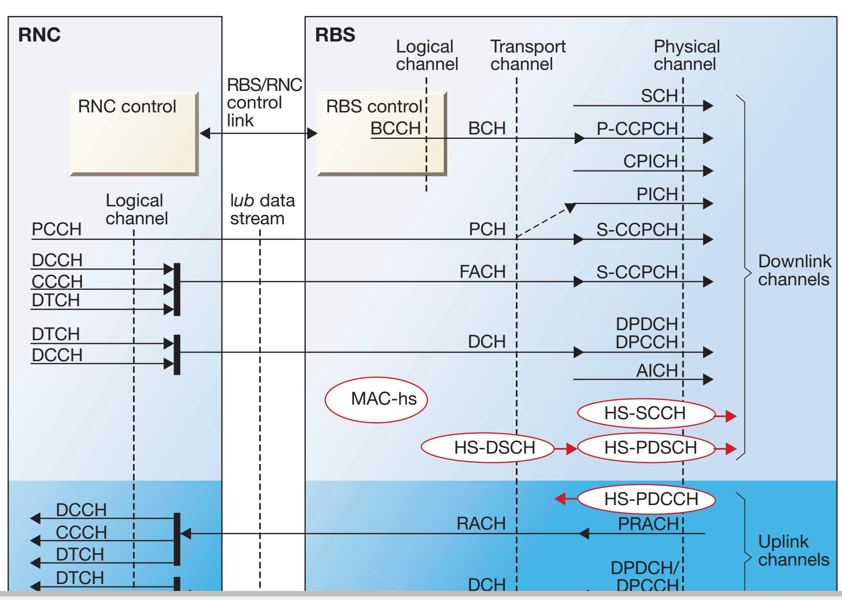


Figure 2
Baseband in RBS and interfaces.

Figure 3
Channel-mapping model. Area marked in red is for HSDPA.



channels. A channel element is defined as the equivalent baseband resource (hardware and software) needed to transmit a voice channel at 30 kbit/s.

Configuration flexibility and efficient use of resources

Operators want a radio base station that can be adapted to handle different site and radio configurations. Ericsson's baseband implementation gives operators this flexibility, allowing them to change radio configurations without having to physically visit the site. Flexible interfaces have been provided between the subsystems of the radio base station, and the baseband parts have been designed in a modular fashion. Each baseband unit provides a certain amount of traffic capacity for dedicated and common transport channels. This modular design enables operators to configure the radio base station for various traffic scenarios and load.

Baseband board types—TX board and RAX board

Obviously, the use of separate baseband downlink and uplink modules makes it easier to upgrade the system and to better adapt it to the asymmetric traffic associated with third-generation services. Ericsson's RBS3000 has two baseband board types: the TX board handles downlink traffic, and the RAX board handles uplink traffic.

Traffic over the air interface is expected to be asymmetrical—that is, there will be more traffic in the downlink than in the uplink. By adding separate TX and RAX boards, operators can increase capacity in small or large increments either symmetrically or asymmetrically.

BOX A, TERMS AND ABBREVIATIONS

3GPP	Third-generation Partnership Project
AICH	Acquisition indication channel
AIU	Antenna interface unit
ASIC	Application-specific integrated circuit
BCCH	Broadcast control channel
BCH	Broadcast channel
BP	Board processor
CCCH	Common control channel
CCH	Common channel
CCTrCH	Coded composite transport channel
CDMA	Code-division multiple access
CPICH	Common pilot channel
CPP	Connectivity packet platform
CRC	Cyclic redundancy check
DCCH	Dedicated control channel
DCH	Dedicated channel
DL-TPC	Downlink TPC
DP	Data processing
DPCCH	Dedicated physical control channel
DPCH	Dedicated physical channel
DPDCH	Dedicated physical data channel
DSCH	Downlink shared channel
DSP	Digital signal processor
DTCH	Dedicated traffic channel
DTX	Discontinuous transmission
FACH	Forward access channel
FP	Frame protocol
FPGA	Field-programmable gate array
GPRS	General packet radio service
GSM	Global system for mobile communication
HS-PDSCH	High-speed physical downlink shared channel
HSDPA	High-speed downlink packet-data access
HS-SCCH	High-speed shared control channel
MCPA	Multicarrier power amplifier
MUX	Multiplexing unit
O&M	Operation and maintenance
PCCH	Paging control channel
P-CCPCH	Primary common control physical channel
PCH	Paging channel
P-CPICH	Primary CPICH
PDC	Personal digital cellular
PICH	Paging indicator channel
PRACH	Physical random access channel
RACH	Random access channel
RAKE	Name of WCDMA receiver
RAX	Random access and receiver
RBS	Radio base station
RF	Radio frequency
RNC	Radio network controller
S-CCPCH	Secondary common control physical channel
SCH	Synchronization channel
SIR	Signal-to-interference ratio
TFCI	Transport format combination indicator
TPC	Transmission power control
TrCH	Transport channel
TRX	Transceiver
TX	Transmitter
UE	User equipment
UL-TPC	Uplink TPC

Modularity of the baseband

Traffic load and distribution vary over time in different sectors and frequencies. The Ericsson baseband architecture employs pooling to optimize the use of available resources. This approach also guarantees that configurations can be flexible. Figure 4 shows the advantages of modularity and pooled resources in two different radio configurations.

Some operators require redundancy in the radio base station. The modular baseband design easily restricts the loss of traffic due to, say, a faulty component or unit in baseband processing.

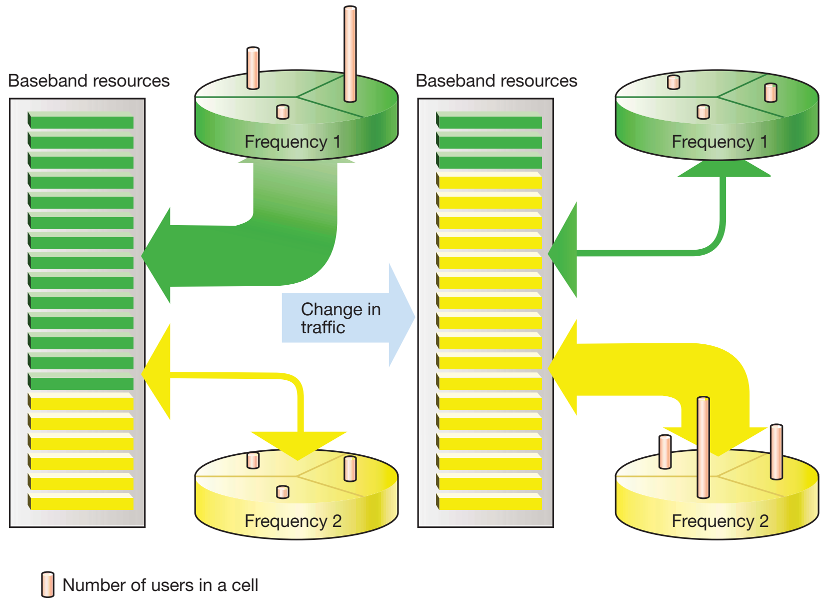


Figure 4
Baseband modularity and pooled resources.

Easy roll-out of third-generation infrastructure

Established GSM and GSM/GPRS operators can more easily roll out third-generation infrastructure by reusing site locations and infrastructure. Most operators starting out in the third-generation business want low-cost, low-capacity RBSs. Later, when the number of subscribers has increased and more advanced services are to be introduced, they will need RBSs that can handle greater traffic capacity in individual cells. The baseband boards have been designed with scalability in mind—greater capacity can be had by adding hardware units (TX boards and RAX boards).

Another way of increasing traffic capacity is to deliver and install prepared hardware on site. As operator needs grow, more capacity can be activated successively by means of software functions. This approach advocates the use of simple, standard hardware configurations.

A further advantage of baseband scalability is that the RBS can be equipped with as many baseband units as needed to satisfy traffic, site conditions, and air-interface capacity for a given frequency band. This helps operators to avoid wasting unnecessary resources.

Future-proof and compatible

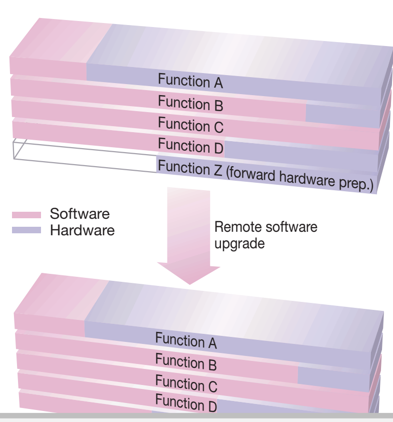
As mentioned above, most operators just starting out in the third-generation business want low-cost, low-content RBSs. Later, however, apart from increasing capacity in the RBS, they will also need more functionality and more advanced features. In designing the baseband, Ericsson has carefully considered various evolution scenarios, making allowances for customer-specific re-

In general, the functions in the physical layer have been implemented in hardware (ASIC) or close to hardware (DSP); the control functions have been implemented in software on DSPs and board processors. To avoid the logistical problems and costs associated with frequent on-site updates or upgrades, Ericsson has prepared the hardware for future functions—these can become available via remote software and firmware updates. Ericsson calls this feature forward hardware compatibility.

On the other hand, new baseband boards must work in environments that use old baseband boards. This is called backward hardware compatibility. Ericsson's baseband hardware and software are forward hardware and backward hardware compatible. Future-proofness—in terms of additional radio configurations, services, functions, and greater capacity—is an importance aspect of Ericsson's baseband design.

Figure 5 illustrates the forward hardware compatibility concept. Function *Z* has been

Figure 5
Forward hardware compatibility.



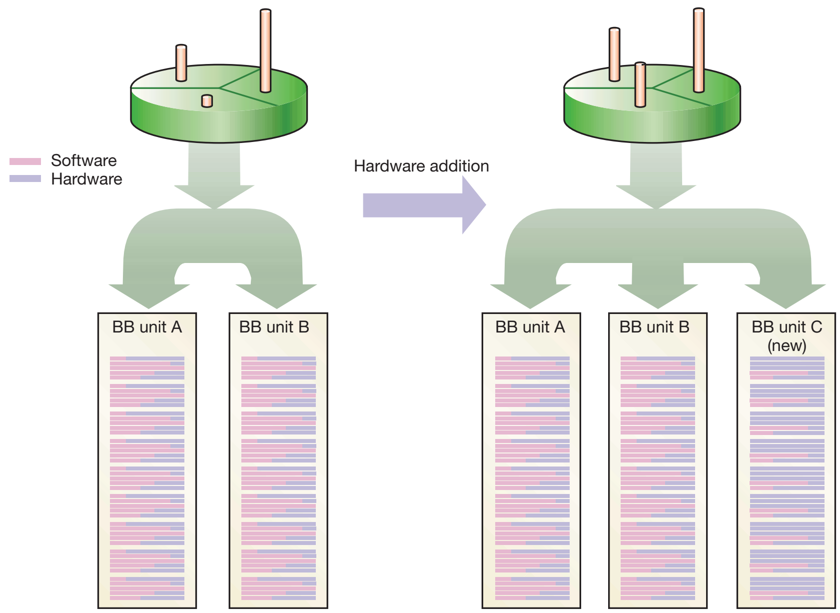


Figure 6
Backward hardware compatibility.

tion. Figure 6 shows the backward hardware compatibility concept. The baseband unit, *C*, is added to the existing RBS to improve functionality and capacity.

Downlink processing board—TX board

Downlink processing functions

Figure 7 shows the main function blocks for processing the downlink. Each of these blocks also contains other baseband functions (not pictured). The first process is frame protocol (FP) handling (pictured left). After confirming when the data frames on the common channels (paging channel, PCH, and forward access channel, FACH) and the dedicated channels (DCH) arrived from the *Iub* interface, the frame protocol handler aligns the frames and extracts the payload part of the data frame. The payload part contains the data of the uncoded transport channels.

For the dedicated channels, the encoding function block

- generates the cyclic redundancy check (CRC);
- concatenates the transport blocks;
- segments the coding blocks;
- inserts the first discontinuous transmission (DTX);
- matches rates; and
- performs the first interleaving.

To fit the 10 ms radio frame, the transport blocks from different transport channels are multiplexed in the multiplexing unit (MUX) function block. This activity is followed by insertion of the second DTX, the second interleaving, and multicode splitting. Data and control information are then sent to the cell-split function block. The control information contains transport format combination indicator (TFCI) bits and corresponding transmission power control (TPC) commands which have been mapped with pilot bits onto the dedicated physical control channel (DPCCH).

After the frame protocols have been handled, the broadcast channel (BCH, which is mapped to the primary common control physical channel, P-CCPCH, and to PCH and FACH) and PCH and FACH (which are mapped to the secondary common control physical dedicated channel, S-CCPCH) are processed in a manner similar to that described for the dedicated channels. The cell-split function identifies the common and dedicated physical channels that belong to

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