Ericsson
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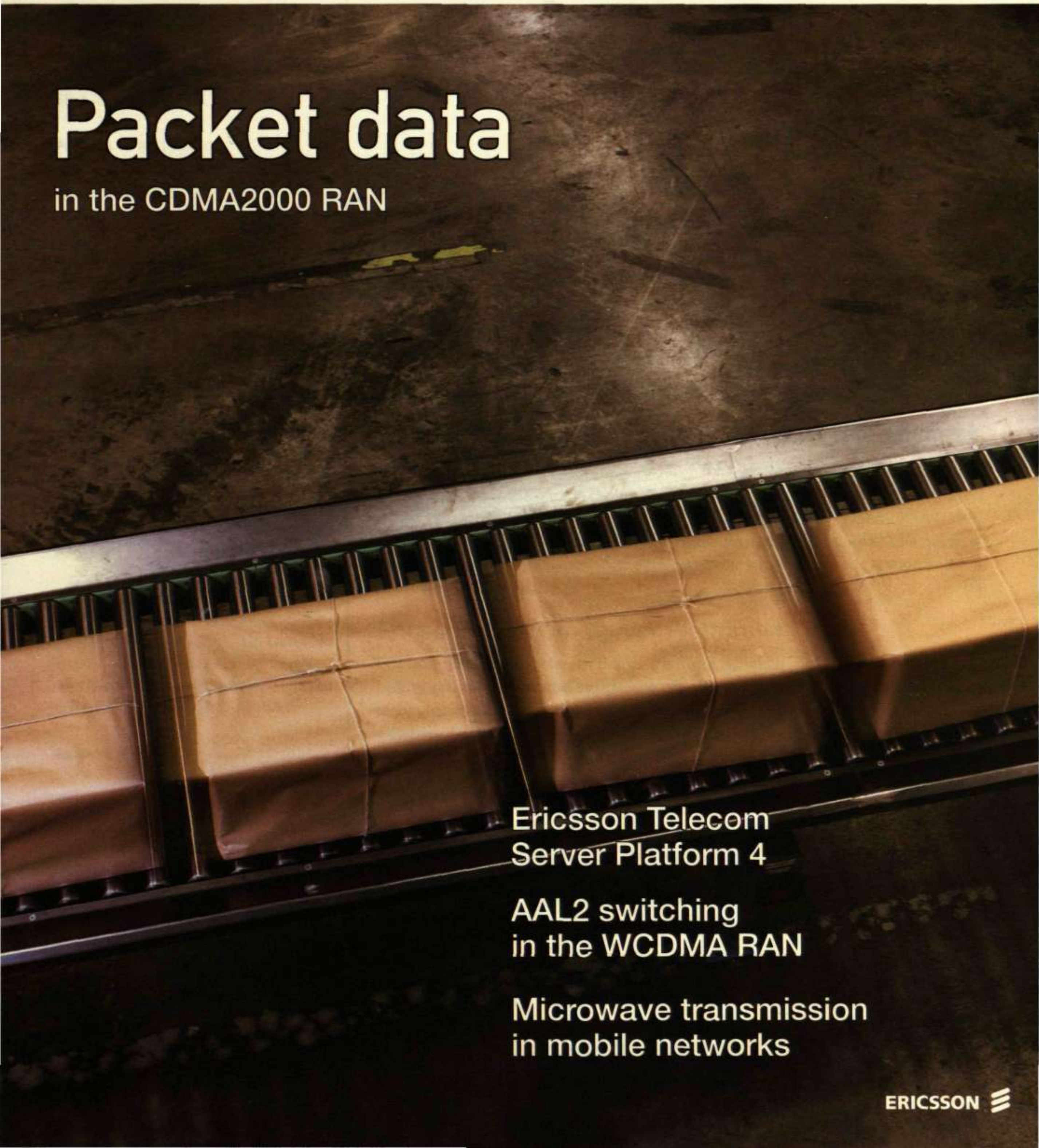
# REVIEW

THE TELECOMMUNICATIONS TECHNOLOGY JOURNAL



## Packet data

in the CDMA2000 RAN

Ericsson Telecom Server Platform 4

AAL2 switching in the WCDMA RAN

Microwave transmission in mobile networks

ERICSSON

**Cover:** A key feature of CDMA2000 1X service is that the packet-data connection between the mobile station and the network is always on. Moreover, as the CDMA2000 air interface continues to evolve, the peak data rates will rise from today's153.6 kbit/s (1X Rev. 0) to 307.2 kbit/s (1X Rev. A) to 2.4 Mbit/s (1xEV-DO) to 3.1 Mbit/s (1xEV-DV), and finally, to All-IP service!

Ericsson
# REVIEW

THE TELECOMMUNICATIONS
TECHNOLOGY JOURNAL

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**Mike Sheppard** joined Ericsson in 1997, initially managing the deployment of cdmaOne infrastructure as part of the BSS project management group. In 1998, he was placed in charge of all project deployments in North America. In April 2000, he was appointed release manager of cdmaOne software products. He recently served as senior product manager in charge of cdmaOne software products and CDMA2000 Release P2. Mike holds a B.S. in electrical engineering from Georgia Southern University and an MBA from Troy State University in Birmingham, Alabama.

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# Editorial

Eric Peterson

This past summer, the Mobile Internet saved my bacon! Earlier in the spring, my uncle e-mailed me saying that he and his wife would be visiting Stockholm together with their son as part of an extended Baltic cruise. He asked if I would be home, and, if so, could we meet? He also gave me the name of the cruise line he would be traveling with and explained that I could monitor the Ports of Stockholm website (www.portsofstockholm.com) to learn when and where his vessel would call. I replied that I would indeed be home and would gladly meet him and play host for a day.

As the appointed day drew nigh, I again confirmed (my uncle had e-mail access on his ship) that I had been monitoring the websites and that I would be on hand when the vessel arrived. Unfortunately, neither my uncle nor I realized that TWO ships from the same cruise line would be calling on Stockholm on the same day and at the same hour. And as you have probably guessed, I went to greet the *other* ship.

I arrived early and anxiously watched as the ship was towed and moored, the gangway was lowered, and hundreds of eager tourists tumbled ashore and were herded toward the queue of sightseeing buses that stood ready to transport them to the city. Two hours later, however, after the last of the buses had departed and only crewmembers remained, I was kicking myself for not thinking to give my uncle the number to my mobile phone: so confident was I in the information I had, that it really hadn't seemed important. Now, of course, I felt downright stupid. The good news is that I get e-mail on my phone. When my uncle could see that I was not there to greet him, he returned to his cabin and e-mailed me the name of his ship and its berth. Moments later I was back inside my car racing to the other side of Stockholm to where my uncle, aunt and cousin were waiting. Thank goodness for the Mobile Internet!

And in case you wondered, we had a terrific visit.

Eric Peterson
*Editor*

# Packet data in the Ericsson CDMA2000 radio access network

Kabir Kasargod, Mike Sheppard and Marco Coscia

**Ericsson's CDMA2000 radio access network consists of a base station controller, radio base stations, a radio network manager and TEMS for CDMA2000. It uses open IOS/IS-2001-compliant interfaces to the mobile switching center (MSC) and packet-data service nodes (PDSN). A key feature of CDMA2000 1X packet-data service is that the packet-data connection between the mobile station and the network is always on.**

**This article discusses the CDMA2000 1X radio access network, the different services it supports, and how always-on, 144 kbit/s packet-data services are implemented. Concepts relating to 144 kbit/s packet-data service are presented from an end-user's perspective.**

## Introduction

In 1999, the International Telecommunication Union (ITU) approved an industry standard for third-generation wireless networks. This standard, called International Mobile Telecommunications-2000 (IMT-2000), is composed of three standards—commonly referred to as WCDMA, CDMA2000 and TD-SCDMA—based on code-division multiple access (CDMA) technology.

Within the CDMA2000 standard, several phases have been defined to support the ITU requirements for third-generation services. Figure 1 shows the evolution of the CDMA2000 standard. CDMA2000 1X, which is based on the IS-2000 standard (Revisions 0 and A), is

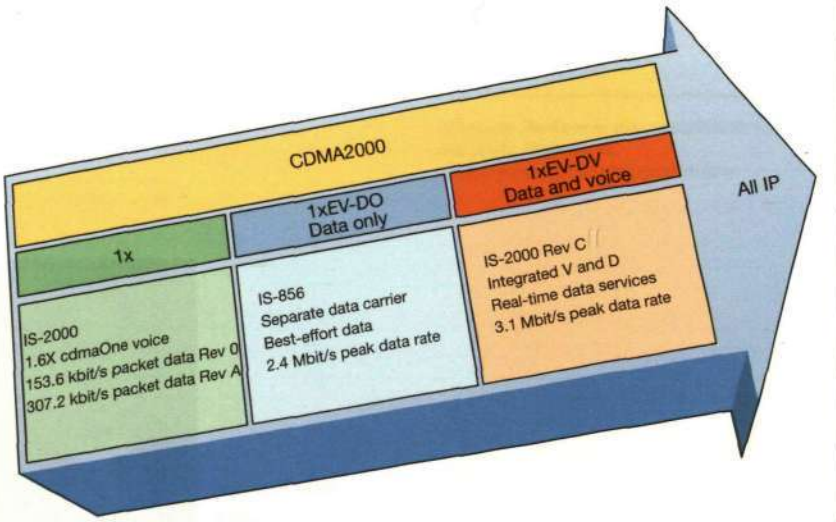
- backward compatible with cdmaOne;
- offers up to twice the voice capacity of cdmaOne systems;
- offers improved terminal battery life;
- supports always-on packet-data sessions; and
- provides data rates of up to 144 kbit/s—with peak over-the-air data rates (including overhead) of 163.2 kbit/s (IS-2000 Rev. 0) and 307.2 kbit/s (IS-2000 Rev. A).

Beyond CDMA2000 1X, the Third-generation Partnership Project 2 (3GPP2) proposes two (1xEV) standards: 1xEV-DO (data only) and 1xEV-DV (data and voice).

CDMA2000 1xEV-DO comprises a separate data carrier that provides best-effort packet-data service with a peak over-the-air data rate of 2.4 Mbit/s. CDMA2000 1xEV-DV provides integrated voice and data with real-time data services and a peak over-the-air data rate of 3.1 Mbit/s.

Ericsson has taken a leadership role in the standardization and commercialization of CDMA2000 services. Its CDMA2000 1X solution is based on true third-generation platforms that protect operator investments and provide a smooth migration path to CDMA2000 1xEV and beyond.

**Figure 1**
**Evolution of the CDMA2000 air-interface standard.**




## Overview of the Ericsson CDMA2000 RAN

The Ericsson CDMA2000 radio access network (Figure 2) consists of

- a base station controller (BSC1120) with built-in packet control function (PCF);
- radio base stations (RBS1127/RBS1130);
- a radio network manager (RNM); and
- TEMS for CDMA2000, for planning and optimization of the radio network.

The BSC controls the RBSs, manages radio network resources, and provides user mobility. It also performs voice compression (vocoding), processes handovers, manages power control to ensure efficient use of network capacity, controls timing and synchronization within the radio access network, and provides interfaces to the RBSs, RNM and packet-data service nodes (PDSN).

The RBSs provide the radio resources and maintain radio links to mobile stations. The RBSs and BSC contain all necessary functions for their own management. The RNM supports operations at the CDMA2000 radio access network level.

TEMS for CDMA2000 enables operators to design integrated networks, test air interfaces, monitor performance, and optimize the design of CDMA2000 radio access and transport networks.

The Ericsson CDMA2000 radio access network uses open IOS/IS-2001-compliant interfaces to the mobile switching center (MSC) and PDSN. Ericsson has demonstrated the capabilities of the IOS interface through numerous inter-vendor deployments. This open-architecture philosophy provides flexibility and interoperability, and protects the investments of network operators who want to provide always-on, 144 kbit/s packet-data service.

Based on the IOS architecture, the BSC is connected to

- the core network (MSC) via an *A1/A2/A5* interface;
- an internal packet control function via an *A8/A9* interface; and
- the PDSN via an *A10/A11* interface.

The BSCs are interconnected within the radio access network via the *A3/A7* interface for inter-BSC soft handover. The RBSs are connected to the BSC via the *Abis* interface. The mobile station is connected to the RBS via the *Um* interface (the air interface) defined by the IS-2000 standard.

Inside the Ericsson CDMA2000 BSC, the PCF provides an interface to the PDSN via the RAN-to-PDSN interface—also known as the *R-P* or *A10/A11* interface. IS-2001 defines the *R-P* interface as two separate interfaces: the *A10* interface, which carries user data, and the *A11* interface, which carries signaling data.

The PCF is responsible for

- managing the packet-data states (active, dormant) of the mobile station;
- relaying packets between the mobile station and the PDSN;
- buffering data received from the PDSN for dormant mobile stations;
- supporting handovers; and
- PDSN selection.

A key feature of CDMA2000 1X packet-data service is that the packet-data connection between the mobile station and the network is always on (Figure 3).

### Always-on service

To set up a packet-data call, a point-to-point protocol (PPP) session must first be established between the PCF and the PDSN. The first time a mobile station connects to the PDSN it establishes the connection via a packet-data call. Once the mobile station has made a PPP connection to the PDSN, it remains connected to the network. All subsequent data transmissions between the mobile station and the PDSN can be initiated by the mobile station or by the PDSN over the PPP connection.

Although the connection is always on, the CDMA2000 1X packet-data service does make provisions to preserve unused radio

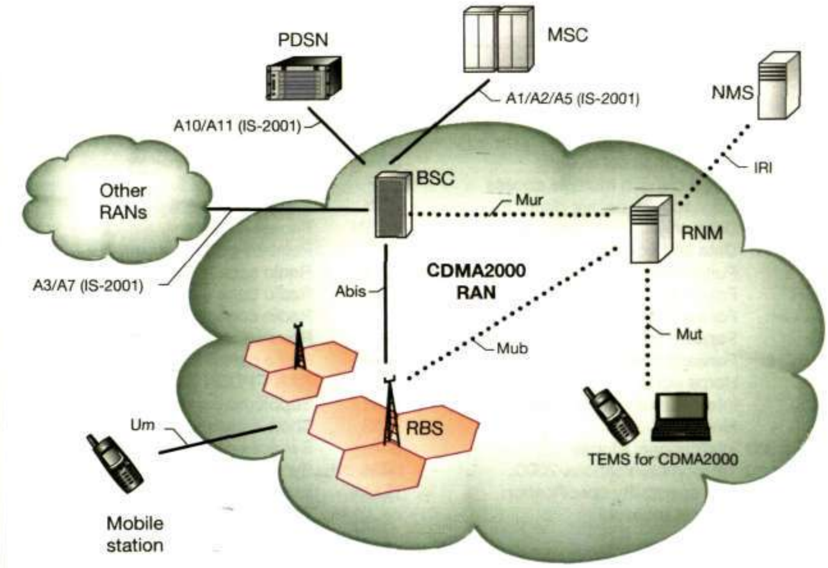
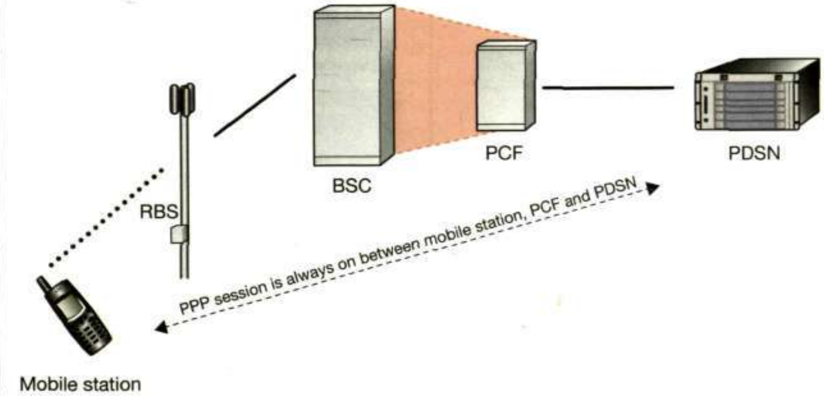



**Figure 2**
**Overview of the radio network.**

**Figure 3**
**Always-on mobile station-to-PDSN connection.**



**BOX A, TERMS AND ABBREVIATIONS**

| | | | |
|---|---|---|---|
| 3GPP2 | Third-generation Partnership Project 2 | ITU | International Telecommunication Union |
| AAL2 | ATM adaptation layer type 2 | MIB | Mobile IP |
| ATM | Asynchronous transfer mode | MSC | Mobile switching center |
| BSC | Base station controller | NMS | Network management system |
| CDMA | Code-division multiple access | O&M | Operation and maintenance |
| CPP | Connectivity packet platform | PCF | Packet control function |
| DO | Data-only | PCN | Packet core network |
| DV | Data and voice | PDSN | Packet-data service node |
| FCH | Fundamental channel | PPP | Point-to-point protocol |
| FER | Frame error rate | RAN | Radio access network |
| F-FCH | Forward FCH | RBS | Radio base station |
| FL | Forward link | RC3 | Radio configuration 3 |
| F-SCH | Forward SCH | RL | Reverse link |
| HA | Home agent | RNM | Radio network manager |
| IMSI | International mobile subscriber identity | R-P | RAN – PDSN (interface) |
| IMT-2000 | International Mobile Telecommunications-2000 | SCH | Supplemental channel |
| IOS | Interoperability specification | SMS | Short message service |
| IP | Internet protocol | SO | Service option |
| | | STM | Synchronous transfer mode |
| | | TEMS | Ericsson network optimization tools |
| | | WCDMA | Wideband CDMA |

link resources. That is, when the mobile station is neither sending nor receiving data and has been inactive for a certain period, the PCF tears down the radio link between the mobile station and the radio access network but maintains the connection (PPP session) between the mobile station and PDSN. This state is called dormancy.

## Overview of the CDMA2000 1X packet-data service

Service options (SO) are used within the radio access network to identify different kinds of service, such as voice, circuit-switched data, packet data, and short message service (SMS). Table 1 shows the designated service options for IS-95 and IS-2000 packet-data service.

Ericsson provides 144 kbit/s packet-data service with over-the-air peak data rate (including overhead) of 163.2 kbit/s as specified in TIA/EIA/IS-707-A-1 service option 33 for IS-2000. When a packet-data call is set up, Ericsson's CDMA2000 radio access network uses radio configuration 3 (RC3) and a fundamental channel (FCH) to provide an initial packet-data rate of 9.6 kbit/s. To ensure backward compatibility with cdmaOne, the fundamental channel in CDMA2000 is similar to that in cdmaOne. The fundamental channel is mainly used for voice services, but in CDMA2000 it also supports low-data-rate packet services (9.6 kbit/s) and can be used to transmit signaling information.

For applications that require data rates exceeding 9.6 kbit/s, Ericsson's CDMA2000 radio access network uses an additional channel—the supplemental channel (SCH). Used in combination to transmit data, the fundamental and supplemental channels can provide 144 kbit/s packet-data service with over-the-air peak data rate (including overhead) of 163.2 kbit/s in the forward (to the mobile station) and reverse (from the mobile station) directions.

The Ericsson CDMA2000 radio access network uses the forward fundamental channel (F-FCH) and the forward supplemental channel (F-SCH) on the forward link, and the reverse fundamental channel (R-FCH) and reverse supplemental channel (R-SCH) on the reverse link. Table 2 shows the data rates of SO 33.

## Delivering CDMA2000 packet data—an end-user's perspective

### CDMA2000 packet-data call set-up

In the example that follows, a user—whom we call Janice—decides to catch up on some work using a data-capable mobile device to initiate a packet-data session and fetch her e-mail.

From the perspective of the radio access

**TABLE 1, PACKET DATA SERVICE OPTIONS**

| Service option | Designated type of service | Max data rate | Associated standards |
|---|---|---|---|
| 7 | Rate set 1: IS-95 packet-data service | 9.6 kbit/s | TIA/EIA/IS-657 |
| 15 | Rate set 2: IS-95 packet-data service | 14.4 kbit/s | TIA/EIA/IS-707 |
| 33 | 144 kbit/s packet-data service | 163.2 kbit/s | TIAEIA/IS-707-A-1 |

153.6 + 9 .6 kbit/s indicates the combination of peak over-the-air data rates provided by the SCH (153.6 kbit/s) and FCH (9.6 kbit/s).

network, the same sequence of messages is used to set up a standard call from a mobile station as that for a packet-data call. There are essentially two requirements for establishing CDMA2000 packet-data calls from a mobile station:

- the allocation of radio resources; and
- the establishment of a PDSN link and PPP session (Figure 4).

After Janice dials the appropriate number and presses send, the mobile station sends (1) an *origination* message with the required packet-data service option (service option 33 for CDMA2000) to the BSC. The BSC, in turn, sends (2) a *connection management service request* message to the MSC, to authorize a radio traffic channel for the call. If Janice is an authorized user of the network, the MSC responds with (3) an *assignment request* message to the BSC, instructing it to allocate the resources needed for the call. Once the radio traffic channel has been established, the BSC sends (4) an *assignment complete* message to the MSC. Janice's mobile station is now authenticated and has the air interface resources it needs for the e-mail session.

The BSC can then generate and send (5) an *A9-setup-A8* message to the PCF, which finishes setting up the data session with the PDSN and responds to the BSC with (6) an *A9-connect-A8* message. If the PCF fails to set up the session, it sends an *A9-release-A8* message. To initiate set-up of an A10 connection to the PDSN, the BSC/PCF sends (7) an *A11 registration request* message to the selected PDSN, which validates the request and, if the request is acceptable, returns (8) a *registration reply* message to indicate acceptance. With the A10 connection in place, link layer and network layer frames pass over the connection in both directions. A point-to-point protocol (PPP) connection (9) is now in place between the mobile station and the PDSN, and Janice can begin communicating over the Internet—for example, by authenticating herself to an Internet service provider. Note: For packet-data calls, a circuit is never allocated between the MSC and BSC, since the data packets are routed directly from the BSC to the PDSN.

## Data rate allocation and de-allocation

After the PPP session has been established between the mobile station and PDSN, if Janice has data to send or receive, Ericsson's CDMA2000 radio access network sets up a radio link for the packet-data call and sets up the fundamental and supplemental channels with appropriate data rates (Table 2). To better understand how a peak over-the-air data rate of up to 163.2 kbit/s is allocated to the end-user in the forward and reverse directions, we will now describe the events that trigger the allocation of the fundamental and supplemental channels, and the factors that determine the maximum allowable data rate associated with the supplemental channel.

**TABLE 2, CDMA2000 1X PACKET-DATA RATES (SO33)**

| F-FCH/ R-FCH | F-SCH/ R-SCH | Peak over-the-air data rate (kbit/s) |
|---|---|---|
| 9.6 | 0.0 | 9.6 |
| 9.6 | 19.2 | 28.8 |
| 9.6 | 38.4 | 48.0 |
| 9.6 | 76.8 | 86.4 |
| 9.6 | 153.6 | 163.2 |

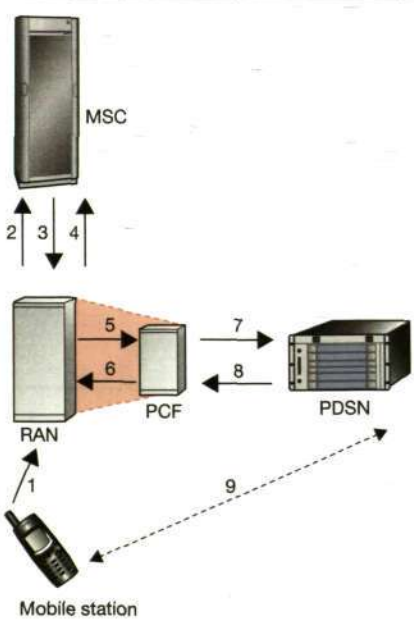



Figure 4
Set-up of a packet-data call.
1 Origination message
2 CM service request message
3 Assignment request
4 Assignment complete
5 A9 - setup - A8 message
6 A9 - connect - A8 message
7 Registration request
8 Registration reply
9 PPP session established

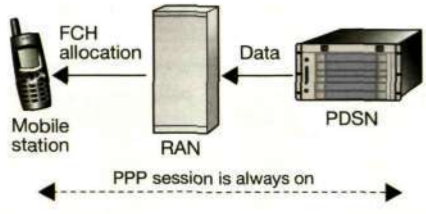



Figure 5
Allocation of the fundamental channel.

### Accessing the FCH and SCH

When there is data to send, the mobile station or network initiates a packet-data session, and a fundamental channel is set up (Figure 5).

The radio access network checks the packet sizes and packet buffer sizes for packets to the mobile station, to determine whether or not it needs to set up the supplemental channel (Figure 6)—that is, it will not set up the supplemental channel unless packet size or packet buffer size exceeds a given threshold or unless the mobile station has requested a supplementary channel.

### Factors that determine the maximum allowable SCH data rate

If the amount of data coming in to the radio access network from the PDSN justifies the use of a supplemental channel, the BSC sets up this channel at the highest data rate allowed or the highest data rate for which resources are available, whichever is less (Figure 6). If the operator permits the network to allocate, say, 16x SCH, and resources are available in the cell, then the BSC sets up a supplemental channel with peak over-the-air data rate (including overhead) of 153.6 kbit/s. A radio admission control algorithm, internal to the BSC, is responsible for allocating the radio resources and Walsh codes that are necessary for packet-data calls.

The maximum data rate of the supplemental channel is determined by the channel conditions of the user. A threshold for satisfactory channel condition is defined for each data rate (2x, 4x, 8x and 16x). The measured channel condition is compared to the required channel condition for each data rate. The highest data rate for which the reported channel condition exceeds the required value becomes the requested data rate for the supplemental channel. To initiate set-up of the supplemental channel, the requested data rate must be greater than 2x, otherwise set-up is aborted. The F-SCH is maintained as long as the channel conditions are satisfactory and as long as enough data is being transmitted.

### De-allocation of the SCH

The supplemental channel is de-allocated when the volume of data being sent to the mobile station can be satisfied using the fundamental channel or if the channel conditions become unsatisfactory for the current rate. Unsatisfactory channel conditions for the chosen rate would lead to excessive frame error rates (FER), which wastes radio resources. A throughput-related metric is used to measure use and channel quality, and the supplemental channel is de-allocated if throughput falls below a given threshold (Figure 7).

### Optimized sector selection for the F-SCH

Ericsson's implementation of the high-speed packet-data allocation of the F-SCH is optimized for high throughput and uses only one radio link to the best possible sector. Instead of using soft handover for the F-SCH, which requires additional and unnecessary radio resources, the best pilot is selected from the FCH active set (sector selection). Analysis of the F-SCH air link and radio link protocol has shown that sector selection works better than soft handover for the F-SCH. Note, however, that soft handover is always used when setting up the fundamental channel, since the signaling sent on the fundamental channel has more stringent channel quality requirements than the F-SCH. Moreover, because radio resources on the reverse link are not as sparse as on the forward link, soft handover is used to improve network reliability on the reverse-link supplemental channel (R-SCH).

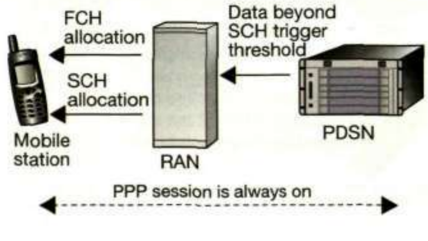



Figure 6
Allocation of the supplemental channel.

## Mobility management

If Janice is on the go while transmitting and receiving data, the connection of her mobile station to the network will have to be managed as the mobile station moves from cell to cell—much the same as is done for circuit-switched services. Moreover, as the mobile station moves, the radio link and connection to the packet core network must be managed regardless of whether the mobile station is in an active or dormant state.

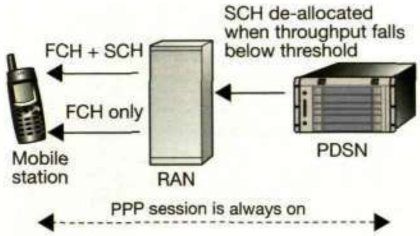



**Figure 7**
**De-allocation of the supplemental channel.**

### Types of handover

Ericsson's CDMA2000 radio access network supports different types of packet-data call handover (Figure 8). A handover can occur between two cells within the same BSC (intra-BSC) or between two cells belonging to different BSCs (inter-BSC). Handovers can be between cells using different frequencies (hard handover) or between cells that use the same frequency (soft handover). Handovers can also occur between sectors of the same cell and frequency (softer handover).

### Packet-data handovers: impact on FCH, F-SCH, R-SCH and PPP session

Below we discuss the impact of packet-data handovers on the fundamental channel (forward and reverse), F-SCH, R-SCH and the PPP session established between the mobile station and the PDSN.

Many types of packet-data handover resemble those for voice service. The following discussion focuses on handover scenarios that differ from those for voice.

### Intra-BSC F-SCH sector selection

When the F-SCH serving sector is no longer the best sector for the F-SCH, the BSC selects another sector to serve the F-SCH (sector selection).

- The serving BSC and PDSN remain the same.
- There is no change in the PPP session.
- The fundamental channel allocated to the packet-data call is undisturbed.
- The F-SCH allocated to the packet-data call is de-allocated from the current serving sector and re-allocated to a new serving sector.

### Intra-BSC hard handover of the FCH and F-SCH/R-SCH

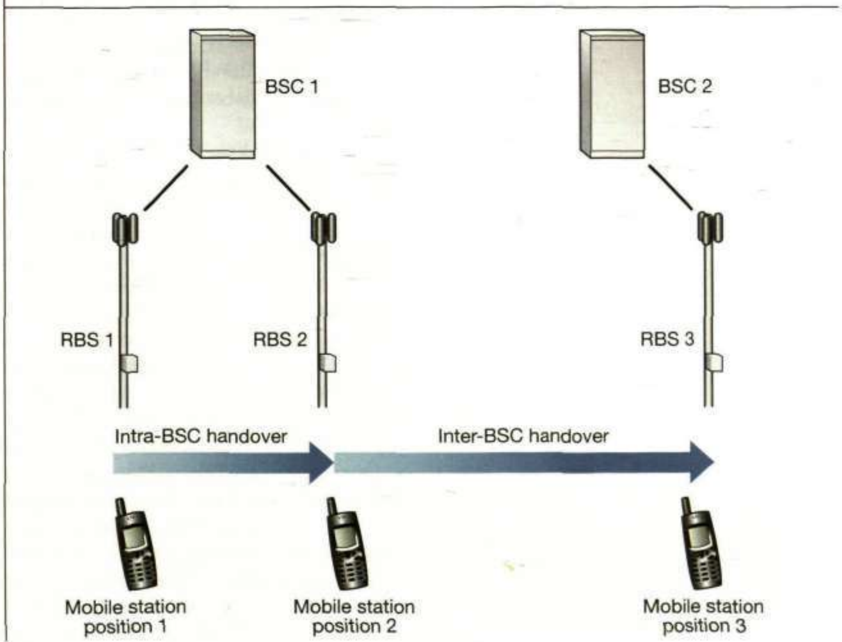
For hard handover of a packet-data call in the serving BSC (intra-BSC hard handover)

- there is no change in the PPP session;
- the F-SCH or R-SCH is de-allocated as a result of the hard handover in the BSC;
- the fundamental channel allocated to the packet-data call is de-allocated and a new fundamental channel is allocated to the call on the new CDMA channel; and
- a new F-SCH or R-SCH can be re-allocated by the BSC after the handover is complete.

### Inter-BSC hard handover of the FCH

For hard handover between BSCs, the source and target BSCs may be connected to the same PDSN or to different PDSNs. If the BSCs are connected to different PDSNs, the

**Figure 8**
**Packet-data handovers.**



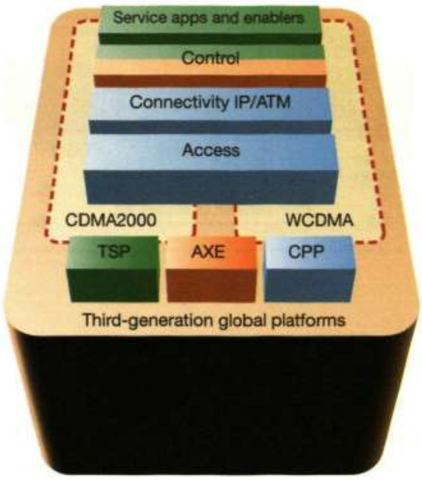



**Figure 9**
**Use of global third-generation platforms.**

mobile station can continue to use the same IP address, provided the mobile station supports the Mobile IP (MIP). When the mobile station moves between different PDSNs, the packets will be forwarded or tunneled by elements within the packet core network (PCN) to the PDSN that is currently serving the mobile station. Therefore, for inter-PDSN (with MIP) or intra-PDSN inter-BSC hard handover

- the mobile station continues to use the same IP address;
- the fundamental channel allocated to the packet-data call is de-allocated and a new fundamental channel is allocated;
- the F-SCH or R-SCH is de-allocated as a result of the inter-BSC hard handover;
- the target BSC becomes the new anchor for the call; and
- a new F-SCH or R-SCH can be re-allocated by the target BSC after handover is complete.

### PDSN selection

Each PCF, which can be connected to multiple PDSNs, uses a PDSN selection algorithm (as specified in the interoperability specification) to balance the load handled by the PDSN when a mobile station moves from one PCF to another. The PCF is configured with the address of every PDSN that is connected to it. The PCF uses the international mobile subscriber identity (IMSI) of the mobile station to hash among the configured PDSN addresses and select a PDSN for the mobile station. This ensures that mobile stations are distributed over all PDSNs connected to a particular PCF. When a mobile station moves between PCFs, the PDSN selection algorithm ensures that the mobile station remains connected to the PDSN during handover to another PCF. This approach maintains the connection between the mobile station and PDSN and allows the mobile station to maintain its original IP address.

## Dormancy

If Janice stops sending and receiving data, her mobile station will transition from an active to a dormant state. As explained above, dormancy is the state of a packet-data call in which the air link has been torn down due to inactivity. This is done to conserve radio link resources. The PPP session between the mobile station and PDSN is maintained (always on) throughout dormancy to ensure rapid reconnection when there is data to transmit.

### Conditions for dormancy

The transition from active to dormant state can be initiated by either the mobile station or the BSC. A mobile station can initiate the transition by instructing the BSC to disconnect the traffic channel through a *release order* message. Similarly, if the inactivity timer at the BSC expires for a given packet-data session, the BSC can initiate a transition of the mobile station to a dormant state by issuing a *release order* message to disconnect the traffic channel for the mobile station.

### Handovers in dormant mode

Handovers for a mobile station in dormant mode are handled by the network. In the dormant state, there are no fundamental or supplementary channels allocated to the user, but the PPP session between the mobile station and the PDSN is maintained through the PDSN selection algorithm as the user moves between PCFs.

### Dormant-to-active state transition

The transition from a dormant to an active state can be initiated by either the mobile station or the BSC. The mobile station can initiate the transition by sending an *origination* message with the packet-data service option. Likewise, the BSC can initiate the transition of a mobile station from dormant to active state by paging it when the BSC receives data addressed to it from the PDSN. The PPP session does not need to be re-established since it is always on. In all other respects, this call is no different from a regular A8 connection set-up procedure. When there is data to send, the fundamental and supplemental channels are allocated by the network in the manner described above.

## Ericsson's implementation

Ericsson is the only wireless vendor with a focused, well-aligned strategy for third-generation wireless networks. Ericsson uses the same third-generation platforms in its WCDMA and CDMA2000 solutions. As a consequence, Ericsson can focus its development resources on improved time to market and enhancements to the product line itself. Figure 9 highlights Ericsson's global platform strategy.

Ericsson's implementation of CDMA2000 1X is based on the connectivity packet platform (CPP, formerly called Cello packet platform) in the radio access network (Figure 10). CPP is used in the Ericsson BSC1120, RBS1127 and RBS1130 as well as in packet core network nodes, such as the PDSN and the home agent (HA). CPP is made up of hardware and software modules that use a cell switch to interconnect processors on different types of device, offering a flexible and scalable operating platform for network products. The physical infrastructure consists of a 19-inch subrack with a cell-switching capacity of 16 Gbit/s and contains clustered processors and device boards with scalable capacity and robustness.

CPP uses the ATM/IP transport system and supports STM-1, OC-3 and other standard physical interfaces. ATM adaptation layer type 2 (AAL2) functionality for signaling and multiplexing, as well as real-time IP functionality, are built into the platform. Likewise, the platform contains an accurate system clock function that can be synchronized to an external source or to any of the line interfaces. Ericsson's CPP is

- future-proof—this provides operators with an economical migration path to future-generation technologies, such as 1xEV;
- modular and flexible—modularity makes it easy to create nodes and products with various configurations and different capacity, reliability, and performance levels. CPP is very flexible in handling the challenges that will be brought upon by 1xEV, such as additional packet data and the mix of voice and data;
- robust—CPP uses a multiprocessor control system on a commercial processor and a real-time operating system with increased robustness for telecommunications-class availability. It uses ATM technology for node communications and switching, ensuring carrier-class quality throughout the radio access network; and
- ready for migration to all-IP systems—CPP is well prepared for easy migration to IP transport when the radio access network migrates to an all-IP network.

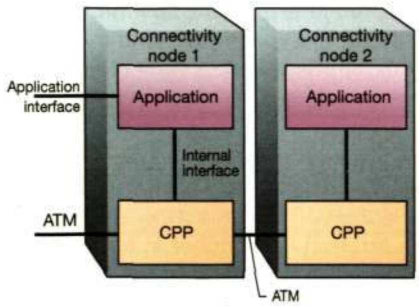



**Figure 10**
**Ericsson's connectivity packet platform (CPP).**

## Conclusion

CDMA2000 is an approved third-generation mobile standard with support for high-speed, always-on, packet-data services. CDMA2000 1X is backward compatible with cdmaOne, provides increased voice capacity and supports packet-data services of 144 kbit/s (peak data rate of up to 163.2 kbit/s).

CDMA2000 1xEV-DO supports data-only services on a single CDMA carrier with best-effort packet data at a peak rate of 2.4 Mbit/s.

CDMA2000 1xEV-DV supports voice and real-time data services on a single CDMA carrier at a peak rate of 3.1 Mbit/s.

Ericsson's CDMA2000 radio access network solution, which is based on the company's global third-generation carrier-class technology (CPP) uses standardized, open interfaces to connect to the packet core network to deliver data services. Through always-on and dormancy features, Ericsson's CDMA2000 radio access network efficiently allocates high data rates to end-users while preserving valuable radio link resources. It has been designed with the future in mind, supporting CDMA2000 1X, today, and providing operators with investment protection and smooth migration to higher packet data rates when CDMA2000 1xEV is introduced.

# Ericsson Telecom Server Platform 4

Victor Ferraro-Esparza, Michael Gudmandsen and Kristofer Olsson

**The marriage of telecommunications and the Internet puts new requirements on equipment. Customers have come to expect the same quality of service as they get from present-day telecommunications networks. At the same time, they expect new services in the multimedia and services domain.**

**We know from experience that modern telecommunications systems are extremely reliable and provide real-time responses. This level of reliability and response cannot currently be achieved using technologies in the Internet domain. On the other hand, the Internet is far richer in terms of content, where pictures (still and moving) are part of today's experience.**

**In an ideal world we would reuse technologies from the data communications industry and combine them with those from telecommunications systems. With the Telecom Server Platform 4, Ericsson has taken a giant step in this direction, combining its know-how and experience of telecommunications, reliable systems, and scalable systems with open technologies, such as Linux, CORBA, SNMP, LDAP and other standards, such as cPCI and *de facto* standards. The result is a carrier-class server which is always on, scalable, and open, and which adds value for Ericsson's customers.**

**Ericsson Review no. 1, 2002 described the Ericsson IP Multimedia solution and the role the Telecom Server Platform plays in this domain. The Telecom Server Platform also plays an important role in delivering services. In this article, the authors describe the Ericsson Telecom Server Platform 4 in greater detail. They also briefly describe the service network framework and give some examples of applications in the services domain.**

## Product overview

The Ericsson Telecom Server Platform 4 is more robust and fault-tolerant than any comparable server technology. It is extremely reliable with unique, linearly scalable capacity, and real-time characteristics, which means that transmission takes place with minimal and controlled delay.

The telecommunications-grade software is enabled by TelORB clusterware, which runs on top of DICOS and Linux. The software incorporates the very latest in signaling system no. 7 (SS7) and built-in node management, with support for the many protocols needed for interoperability between the Telecom Server Platform and operations support systems (OSS).

In its make-up, the Telecom Server Platform combines Ericsson's long tradition of designing robust and reliable hardware with commercially available components. The result is an open hardware architecture with excellent characteristics: scalable capacity, telecommunications-grade reliability, small footprint and minimal power consumption.

### Hardware

The Telecom Server Platform uses commercially available hardware with ample capacity and dependable node performance. This lowers the cost of installation, operation, and maintenance.

The hardware fulfills all telecommunications requirements regarding power consumption, low electromagnetic radiation, reliable equipment practice, and reliable connectors. This ensures trouble-free operation. What is more, the modular design facilitates upgrading.

Some key features of the hardware are redundancy in all hardware components, "hot-swap" hardware replacement, a modular platform for maximum flexibility, standard

**BOX A, TERMS AND ABBREVIATIONS**

| | |
|---|---|
| 3GPP | Third-generation Partnership Project |
| AAA | Authentication, authorization and accounting |
| API | Application program interface |
| ASP | Application service provider |
| CAMEL | Customized applications for mobile network-enhanced logic |
| CAP | CAMEL application protocol |
| CM | Configuration management |
| CORBA | Common object request broker architecture |
| cPCI | Compact PCI |
| CPI | Customer product information |
| DICOS | Object-oriented operating system with excellent real-time characteristics. Developed by Ericsson. |
| E1/T1 | PDH transmission frame formats for 2 Mbit/s (E1) alt. 1.5 Mbit/s (T1) transmission rates |
| FM | Fault management |
| FPGA | Field-programmable gate array |
| GEM | Generic Ericsson magazine |
| GESB | Gigabit Ethernet switch board |
| GUI | Graphical user interface |
| HTTP | Hypertext transfer protocol |
| IIOP | Internet inter-ORB protocol |
| I/O | Input/output |
| IPC | Inter-processor communication |
| IPv4 | Internet protocol version 4 |
| ISR | In-system reconfigureable FPGA |
| J2EE | Java 2 Enterprise Edition |
| LDAP | Lightweight directory access protocol |
| MAP | Mobile application part |
| MIP | Mobile IP |
| NAS | Network access server |
| O&M | Operation and maintenance |
| ORB | Object request broker |
| OSA | Open system architecture |
| OSS | Operations support system |
| PCI | Peripheral computer interconnect |
| PM | Performance management |
| RADIUS | Remote access dial-in user service |
| RAM | Random access memory |
| RMI | Remote method invocation |
| RPC | Remote procedure call |
| SCB | Support & connection board |
| SCS | Service capability server |
| SDRAM | Synchronous dynamic RAM |
| SIGTRAN | Signaling transport |
| SNF | Service network framework |
| SNMP | Simple network management protocol |
| SOAP | Simple object access protocol |
| SS7 | Signaling system no. 7 |
| SSL | Secure socket layer |
| TCP | Transmission control protocol |
| TMN | Telecommunications management network |
| UDDI | Universal description, discovery and integration |
| UDP | User datagram protocol |
| W3C | World Wide Web Consortium |
| WSDL | Web services description language |
| XML | Extensible markup language |

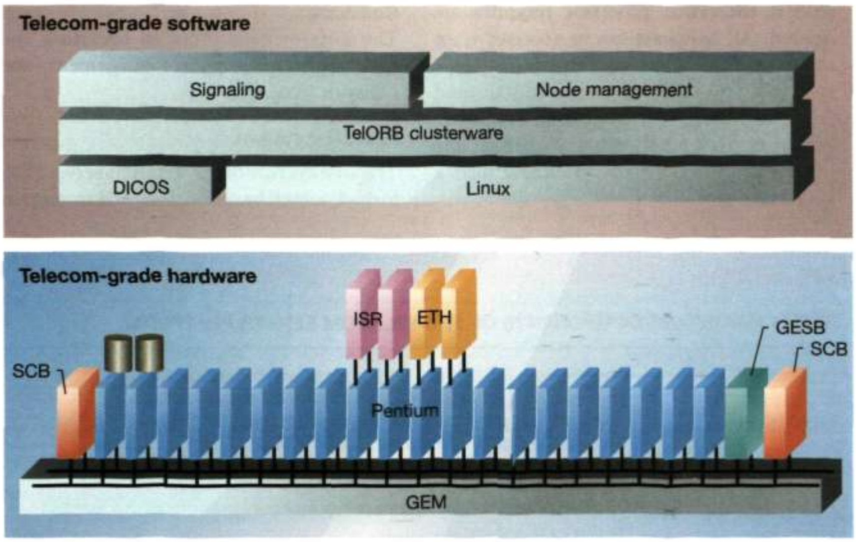



Figure 1
The Telecom Server Platform consists of telecom-grade hardware and software.

hardware interface boards, industry-standard components (creating a future-proof architecture), and optional geographical node redundancy for additional dependability.

The Telecom Server Platform 4 can be duplicated in a redundant standby node. That is, in case of failure, the load is automatically redistributed within the node or, in the case of geographical node redundancy, a remote standby node can take over the functions of the primary node.

The ability to hot-swap hardware allows operators to replace any component at any time without affecting system performance. In a market of converging technologies and standards, the use of industry-standard components creates an architecture that is future-proof, scalable, flexible and cost-effective.

The hardware platform includes processor modules (with or without peripherals), signaling processors, Ethernet switches, power supplies and fans. All processors are standard, commercial, off-the-shelf, single-board cPCI computers (Box B).

The unit is housed in an Ericsson cabinet (BYB 501). An expansion cabinet is avail-

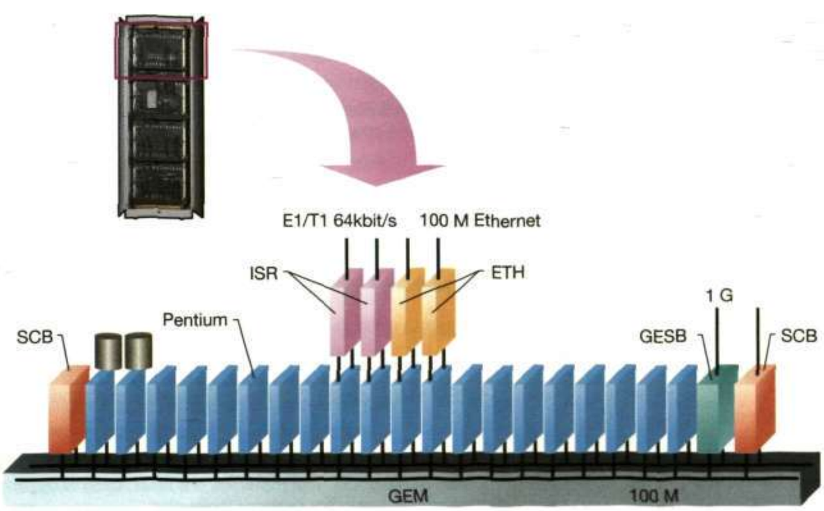



Figure 2
Each subrack consists of $n$+1 duplicated processors connected via duplicated 100 Mbit/s Ethernet. The subracks are interconnected via 1 Gbit/s Ethernet. Every component is at least duplicated.

able if additional processor modules are needed. All hardware can be accessed from the front panel, ensuring easy maintenance and replacement. To ensure high quality and efficient installation, all external cables are connected to a patch panel. Together, the main cabinet and expansion cabinet form a single node.

## Software

The software consists of an operating system, clusterware, node management, and network signaling.

### *Operating system*

The architecture of the Telecom Server Platform 4, which has been designed to support

**BOX B, HARDWARE COMPONENTS OF THE TELECOM SERVER PLATFORM**

| | |
|---|---|
| Processors | Intel Pentium III 700 MHz cPCI boards with 1 GB SDRAM. |
| E1/T1/J1 ports | To execute scalable SS7/ITU-T/China/ANSI protocol stacks. |
| Ethernet ports | 100 Mbit/s Ethernet connections used for external IP communication, such as the signaling transport (SIGTRAN) protocol. |
| Input/output devices | DVD: one drive for input purposes, including initial loading.<br>Tape drive: one 20 GB drive, for example, for backups. |
| Hard drives | Up to 14 x 18.2 GB storage capacity for every executable unit needed for start-up and backup. |
| Patch panel | A jack frame to which the cables in the cabinet are terminated, and to which all external cabling is connected. |
| Alarm collector | Collects alarms from fans and supply voltage supervision at level-1 switches in the magazines. |
| GEM | Generic Ericsson magazine (GEM)—a standard subrack that provides a cost-effective solution with small footprint. Each GEM has a 100 Mbit/s Ethernet level-1 switch that connects all processor boards. A 1 Gbit/s Ethernet level-2 switch interconnects the magazines. The switches are duplicated for redundancy. |
| Cabinet | The Ericsson BYB 501 uses forced-air ventilation, allowing heat to dissipate through the bottom and out at the top of the cabinet. Ericsson expansion cabinets are available. |
| Power supply | Input to the cabinet is -48 volts. |

| **Capacities** | **Maxi** | **Midi** | **Mini** | **Micro** |
|---|---|---|---|---|
| E1/T1 connections | 24 | 16 | 16 | 8 |
| ITU No. 7/SS7 signaling channels | 192(E1)/144(T1) | 128(E1)/96(T1) | 128(E1)/96(T1) | 64 |
| Ethernet ports | 32 | 28 | 22 | 12 |
| Processors | 42 | 31 | 21 | 10 |
| RAM data storage | 42 GB | 31 GB | 21 GB | 10 GB |
| DVD | 1 | 1 | 1 | 0 |
| Tape streamer (20GB) | 1 | 1 | 1 | 0 |

**Environmental requirements**

| | |
|---|---|
| Recommended minimum ceiling height: | 210 cm |
| Relative humidity (min-max): | 20-80% |
| Temperature (min-max): | +5° to 40°C* |
| Temperature (normal operation): | +20°C |

* The tape streamer/tapes are a limiting factor when it comes to average temperature and humidity range. If the temperature reaches +35°C, the tape streamer tapes stretch, which leads to loss of data.

**Agency approvals**

The hardware has been designed to comply with NEBS level 3.
Seismic vibration, EN 300 019-2-3 and GR-63-CORE zone 4.
EMC - EN 300 386 class B,
Part 15, Subpart B, Class B/Federal Communications Commission (FCC) according to GR-1089-CORE.
Product safety - EN 609 50, IEC 609 50 and ANSI/UL 1950, third edition.

**Design for environment**

The Telecom Server Platform complies with Ericsson's policy to avoid the use of banned and restricted substances.

**End-of-life treatment**

Ericsson offers recycling services for old Ericsson products. The materials are taken care of by approved recycling companies in compliance with EU or other national legislation.

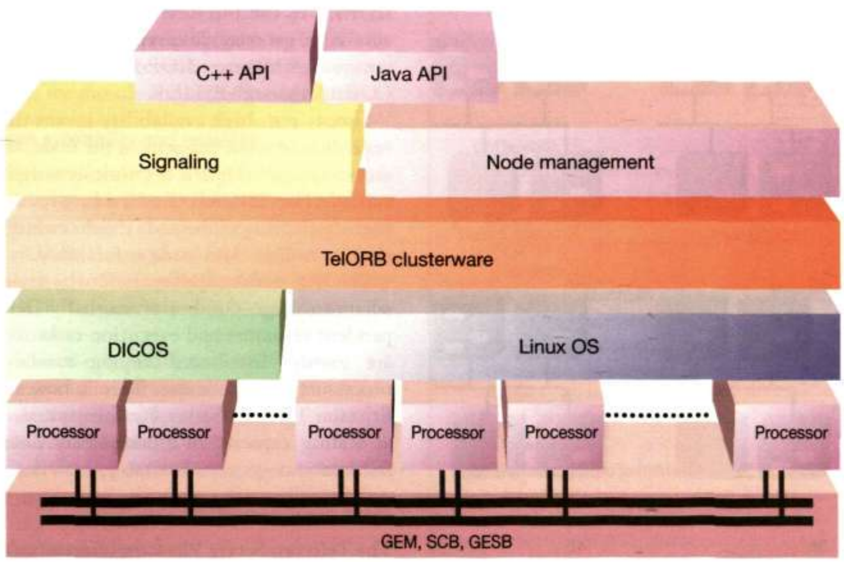



Figure 3
**Software architecture of the Telecom Server platform. The TelORB clusterware also controls the Linux processors in the cluster.**

different commercial hardware and multiple operating systems, provides the most appropriate executing environment for processes. The current version of the Telecom Server Platform uses the Linux operating system for UNIX-like performance, and DICOS for real-time, mission-critical tasks.

DICOS, which is based on queuing theory, offers soft real-time response. This kind of real-time performance is suitable for telecommunications and data communications applications, especially for database clusters.

### *TelORB clusterware*

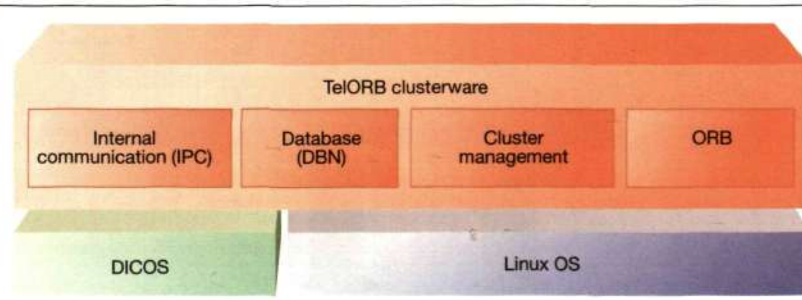
The communication layer of the TelORB clusterware connects the different processors to each other to enable inter-processor communication (IPC). Internally, the TelORB clusterware uses the lightweight protocol IPC to manage duplicated Ethernet backbones. When communicating to the external world, it uses the transmission control protocol (TCP), user datagram protocol (UDP), and IPv4.

A built-in object-oriented database provides persistent storage in RAM. The database is thus always held in primary memory and distributed over the processors. All data is replicated and stored on more than one processor. Should a subroutine or processor fail, the entire database remains available to the software.

The software management layer automatically configures the executing software to ensure that it runs efficiently on any of the processors available to the TelORB cluster. It provides support for software upgrades and monitors and manages software components to ensure high availability. It also supports binaries from third-party vendors. The node-management function includes an element manager that configures and manages every managed object of the TelORB clusterware and operating system.

An object request broker based on the common object request broker architecture (CORBA) has been incorporated to allow the TelORB system to communicate with other systems and the graphical user interfaces used to manage them. It supports

Figure 4
**The architecture of the TelORB clusterware.**



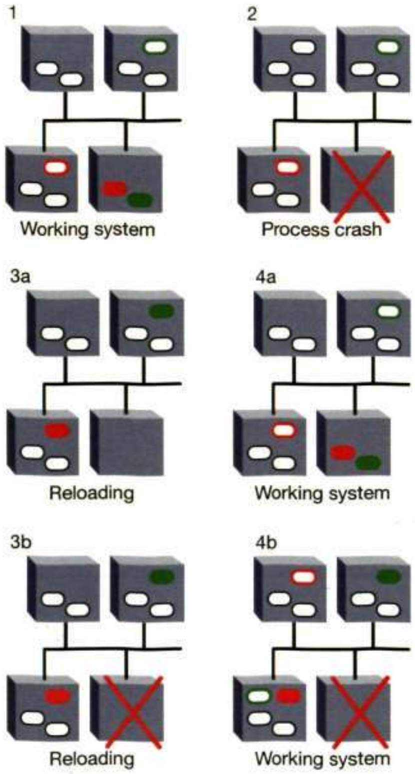
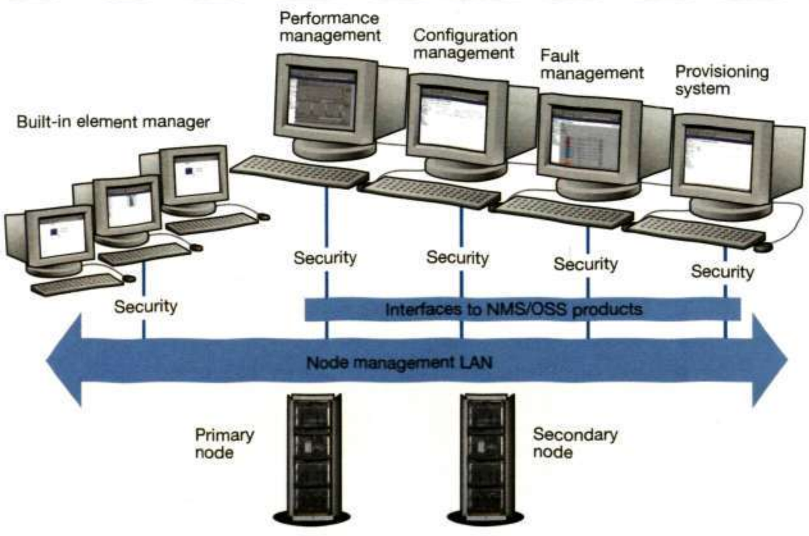



Figure 5
The TelORB clusterware handles hardware and software faults. All data is duplicated (1 & 2).
When a software fault occurs, the processor is restarted and the processes and data are restored (3a & 4a).
When a hardware fault occurs, the processor is taken out of service and new duplicates of the data are made in the cluster (3b & 4b).

Figure 6
Node management in the Telecom Server Platform.




IIOP1.1 to the Internet inter-ORB protocol (IIOP) gateway, Java remote method invocation (RMI) over IIOP/IPC, and secure CORBA through SSLIOP.

Simply put, high availability means that regardless of what happens to the node, the services supplied by the network are not disturbed. The TelORB clusterware provides high availability to the node thanks to inter-node as well as intra-node redundancy.

TelORB enables applications to be divided into a large number of mutually independent resources and execution tasks that are evenly distributed among available processors in the cluster. This is how the Ericsson Telecom Server Platform succeeds at scaling capacity in a completely linear fashion.

*Node management*

The Telecom Server Platform offers a node-management solution based on the telecommunications management network (TMN) model. To better align with operator requirements and industry trends, the node-management system also incorporates other standards, such as CORBA, lightweight directory access protocol (LDAP), hypertext transfer protocol (HTTP) and the simple network management protocol (SNMP).

The node-management system implements a manager-to-agent architecture that integrates the node into external network-management and customer-administration systems using standard protocols to communicate with external systems.

In the Telecom Server Platform 4, the node-management function incorporates fault management (FM), configuration management (CM), provisioning support, performance management (PM), logging service (and log querying), an XML exporter, an element manager, and license management.

*Network signaling*

The signaling solution of the Telecom Server Platform can handle SS7 and Internet protocols. The SS7 protocol is still the most commonly used protocol for data intercommunication in telecommunications networks. The SS7 signaling stack of the Telecom Server Platform 4 is the latest in SS7 technology and features a scalable implementation that can be distributed over the processors used for traffic handling. The design includes a front-end process for terminating the E1/T1 interfaces, and a back-end process for the upper layers of the stack.

## Operator benefits

The Telecom Server Platform is the foundation for several revenue-generating applications for mobile and wire-line operators.

### *High availability and reliability*

High availability is a must in today's modern networks. The Telecom Server Platform achieves high availability through the TelORB clusterware and highly reliable hardware. The main characteristics of the TelORB clusterware can be summarized as follows:

- always-on operation;
- automatic software recovery;
- data replication;
- overload control;
- software updates during operation;
- upgrade of operating system allowed during operation;
- online backup;
- hot-swap hardware replacement; and
- optional geographical node redundancy.

### *Scalability*

Besides high network availability, operators also want scalable network nodes. The Telecom Server Platform has been designed with scalability in mind, ensuring that the initial investment suits customer needs, and that the system can grow with the business. Also, because it is built on commercial hardware, the Telecom Server Platform benefits from continuous enhancements in the processor industry. The modular architecture facilitates rapid expansion of capacity when and where needed. This can be achieved through predefined expansion paths between the configured cabinets.

### *Cost reduction*

The Telecom Server Platform uses commercial, off-the-shelf hardware and software. Operators can thus employ best-in-class hardware and software, and benefit from economies of scale. Because it is scalable and supports co-location, the Telecom Server Platform allows operators to add new applications on a single node in accordance with market demand.

The Telecom Server Platform node management uses a Web-based graphical user interface (GUI) that enables operator staff to access all O&M tasks online—on- and off-site (Figure 7). This functionality reduces delays and travel costs, which, in turn, reduces the total cost of ownership.

Compared to other solutions on the market, the Telecom Server Platform is a total-

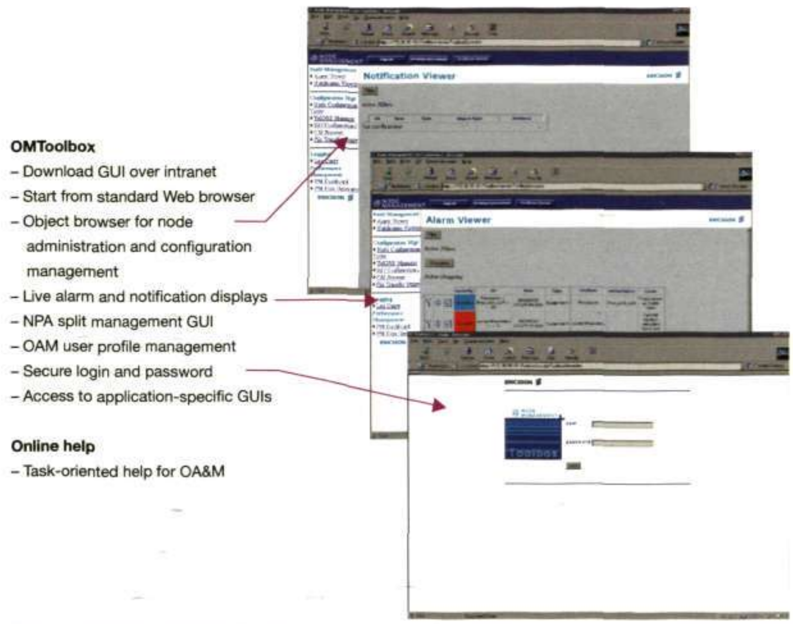
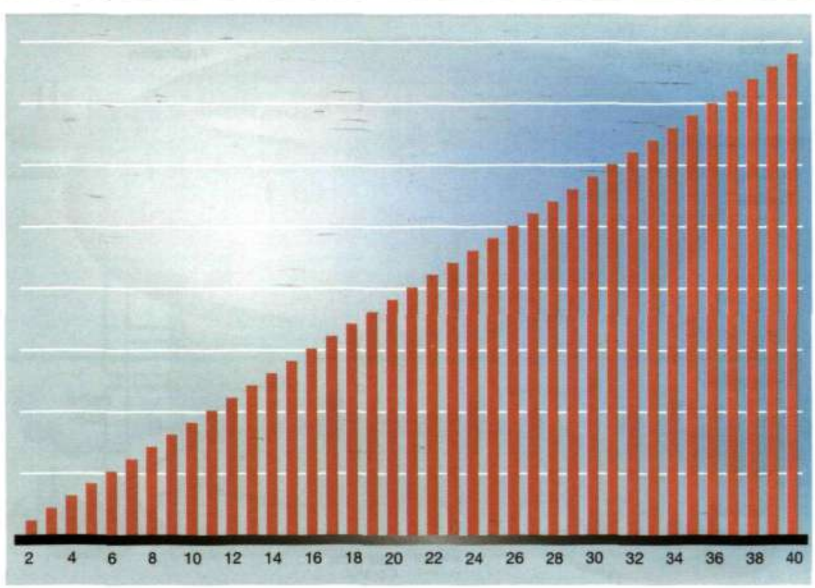



Figure 7
**A built-in Web-based node management GUI enables staff to access all O&M tasks online.**

Figure 8
**The Telecom Server Platform scales linearly. Customers can thus increase capacity as traffic increases.**



ly integrated solution in a very compact node with small footprint.

The extensive set of O&M and provisioning protocols makes it easy to integrate the Telecom Server Platform into existing O&M infrastructures.

## Service network framework

The service layer represents the top layer in Ericsson's three-tier architectural model (Figure 9). The features and functions offered in the service layer pertain both to end-users and the operator of the network infrastructure. They are often offered in the form of an XML Web service interface.

Architectural and design decisions for products and solutions in the service layer are guided through the service network framework (SNF), which is Ericsson's textbook on how system development can be shifted toward horizontally layered systems. The SNF, which provides standards and guidelines for the system structure, capabilities, and interaction, is an architectural framework that consists of reusable designs for products and solutions in the service layer.

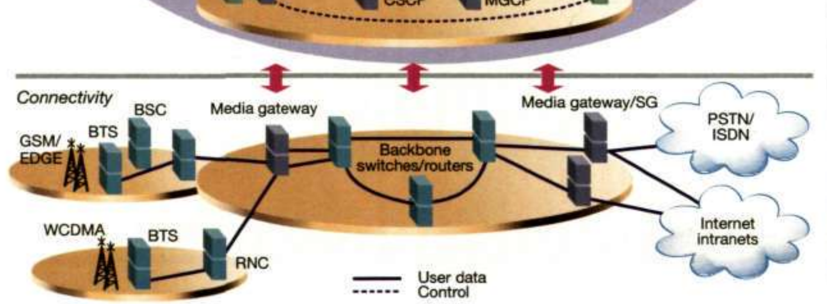
The SNF also forms the foundation for reuse. It has always been difficult to reuse objects from different sources, due to a lack of standards that define how objects should be constructed, what properties they should have, and how they should interact. The SNF provides these standards.

Similarly, the SNF provides specifications (or references to specifications) for common management, provisioning, charging, and shared services. Its service specifications are based on open-standard protocols. Apart from the implied need for IP connectivity, the SNF does not stipulate any specific operating environment.

In addition to the actual specifications, the SNF delivers an architectural framework that is designed to accommodate extensions and grow in the future, yielding a tool for expressing a common architectural direction for the service layer. The SNF is influenced by the following mainstream technologies:

- The application server—considerable Internet application development is conducted according to the Web application paradigm in which the application server deploys the application and provides the run-time and characteristics model.
- The directory server—enterprise and Internet computing domains tend more and more to use LDAP-capable directory servers as repositories of user and resource data. Many products and solutions in these domains interoperate easily with LDAP-capable directory servers.
- The distributed computing paradigm—the industry predominantly employs networks of computers to meet the challenges of scalability and availability. Distributed computing patterns, such as *n*-tier architectures, are used in combination with distributed computing technologies, such as CORBA and COM+, to provide system architectures that lend themselves to distribution over large networks of computers.
- The Java language and the Java 2 Enterprise Edition (J2EE) platform—in recent years we have seen a large gain in server-side Internet and enterprise developer momentum for the Java language with its associated server-side platform specification, J2EE.
- The Web services paradigm—there is a growing trend in distributed computing technology to expose traditional remote procedure call (RPC) services via universally accessible extensible markup language (XML) interfaces using methods standardized by the World Wide Web

**Figure 9**
**Ericsson's horizontally layered network architecture.**



Consortium (W3C) for universal description, discovery and integration (UDDI), the Web services description language (WSDL), and the simple object access protocol (SOAP). The widespread availability of Web services will greatly increase the variety of applications that can be created and deployed in a cost-effective way. The paradigm is simple, universally interoperable and pervasive.

Like the SNF, the operating environment of the Telecom Server Platform also supports and employs these technologies. The products and solutions that leverage the service network framework of reusable designs take a decisive step toward becoming highly scalable, manageable, standards-oriented, open and interoperable, secure and modular. By default, these services are provided in the operating environment of the Telecom Server Platform and are thus facilitated in products and services designed for the service layer.

Collections of products and solutions (systems) that use the technologies and provide the qualities defined above can be deployed to create services networks. Services that target operators and end-users are offered by the services of individual systems. This means that the size of a service network (in terms of the number of constituent systems) can vary and is related to the needs of the business it serves and the nature of the surrounding technical environment in which it is deployed.

## Benefits to applications

### Ericsson AAA Server

The Ericsson AAA Server provides the authentication, authorization, and accounting (AAA) functions that network operators and service providers need to provide Internet access. The key roles of the server are

- authentication—verification of the identity of an entity (user or application) prevents unauthorized actions and use of resources and services;
- authorization—end-users gain access to the network services and resources that match their profiles; and
- accounting—accounting data is collected and consolidated at the end of an IP session, thereby enabling the service provider to charge end-users on virtually any basis (connection time, amount of data transferred, services accessed, and so on). Billing records can be provided and distributed in customized and flexible formats.

The Ericsson AAA Server provides all the basic AAA functions defined in the RADIUS standard (RFC 2865, 2866). It also supports the DIAMETER protocol, which consists of the base protocol and certain specific DIAMETER applications, such as extensions for network access servers (NAS), Mobile-IP (MIP), strong security, and resource management.

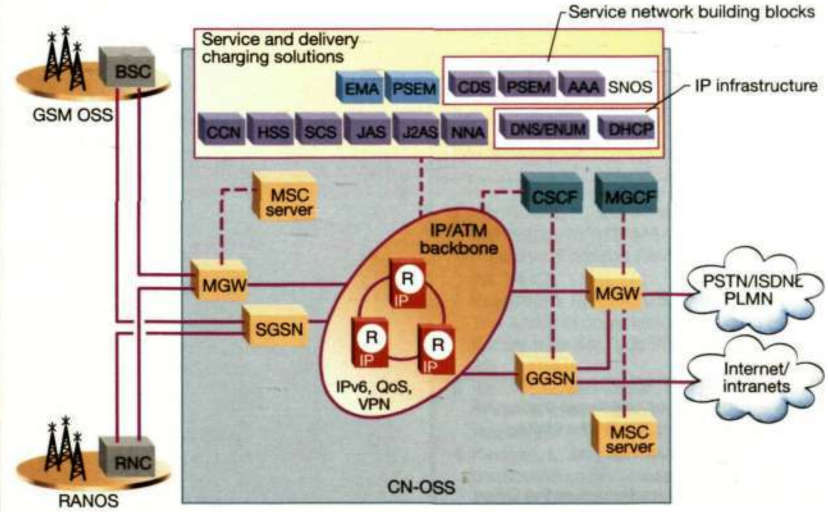
For services to work properly, the Ericsson AAA Server must be available at all times. This puts stringent requirements on the reliability of hardware and software. Lab trials based on a typical traffic model show that the Ericsson AAA Server easily scales to support from 250,000 to more than 5 million subscribers. Moreover, at 50% load it performs more than 2,000 transactions per second.

The inherent characteristics of the Telecom Server Platform are important for the Ericsson AAA Server: it enables the Ericsson AAA Server to scale from small to large systems, gives real-time responses to requests, and is always available.

### Ericsson SCS

One enabler in the service network is the Ericsson Service Capability Server (SCS), which uses the capabilities of the Telecom Server Platform for real-time execution of services, open interfaces and scalability. The

**Figure 10**
**Examples of applications that use the Telecom Server Platform in the core network.**



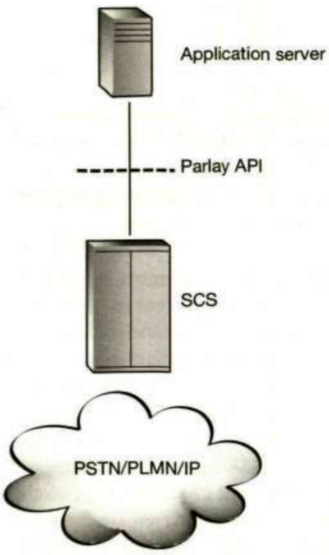



**Figure 11**
**Application service providers (ASP) access the network via the service capability server (SCS) using the standardized Parlay interface.**

aims of the SCS are to encourage the development of innovative services and shorten time to market for new applications. It provides open application program interfaces (API) for call control, user interaction and user status and location according to the Parlay/3GPP-OSA standards. Applications and application servers in the network can thus access network service resources regardless of platform and underlying network technology.

The Ericsson SCS is a Parlay gateway that gives various application services transparent access to network capabilities. It gives applications designed according to the Parlay API specification access to network resources in a controlled and secure way. It also functions as a firewall, ensuring that access to the telecommunications network is securely managed. This means that new players, such as application service providers (ASP) and virtual operators, can enter the market and offer services on top of the telecommunications network as a complement to the services of the network operator.

The Ericsson SCS map translates Parlay commands to different network protocols (such as CS1, CS1+, CAPv2, and MAP). In general, the Parlay API is independent of the underlying network. The vendor of the Parlay gateway decides which network protocols will be implemented.

One important role of Parlay is to hide the network complexity from the designer. Provided he complies with the Parlay specification, the designer should not be required to have in-depth knowledge of the underlying networks. Since Parlay is independent of the network and the programming language, the entire market for application development can instead concentrate on developing services. This means that the applications can be developed more quickly

**TRADEMARKS**

Java is a trademark or registered trademark of Sun Microsystems, Inc. in the United States and other countries.

UNIX is a registered trademark of the Open Group.

and at less cost. It also means that more innovative applications can be released to the market, helping operators to enrich their service offering, reduce churn, attract more subscribers and increase the use of airtime and revenues.

Ericsson supports application developers through its third-party program in Ericsson Mobility World. This support includes a website with a simulator, and the certification of applications. Where Parlay/OSA is concerned, Ericsson is currently partnering with Solomio, Appium and Wirenix, plus a number of associates.

A customer demonstration center strengthens and supports the sales process by showing that the Ericsson SCS and third-party applications actually work on the network. The customer demonstration center is also used to verify and test third-party applications.

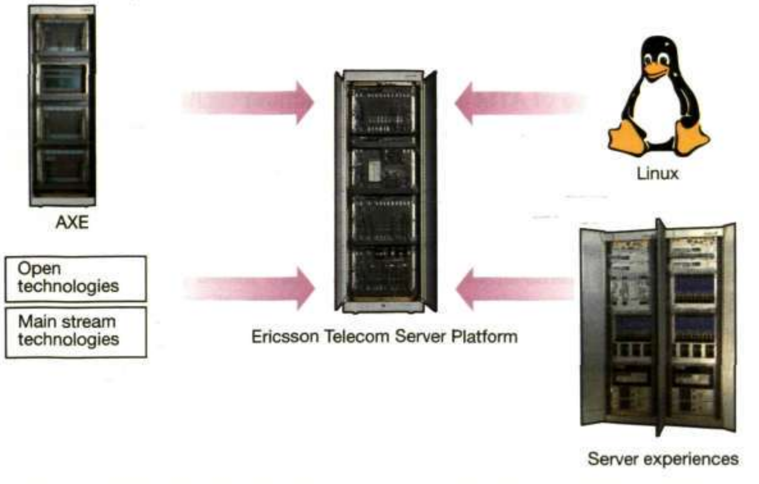



**Figure 12**
**The Ericsson Telecom Server Platform combines the best of the telecommunications world with open Internet technologies.**

## Conclusion

*Ericsson's Telecom Server Platform 4* joins the best of two worlds by integrating IT technologies into a telecommunications-grade server. Many of the applications that use the Telecom Server Platform benefit from its inherent characteristics.

Besides offering the excellent characteristics required for telecommunications systems, the Telecom Server Platform 4 incorporates the latest in open technologies, for example, Linux, which is an important enabler. Ericsson is working actively with Linux standardization bodies, such as the Open Source Development Lab, to make certain that a Linux standard is made available and distributed to the telecommunications industry. The addition of Ericsson's TelORB clusterware to the Linux software gives the system characteristics needed in a telecommunications environment.

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# AAL2 switching in the WCDMA radio access network

Bo Karlander, Szilveszter Nádas, Sandor Rácz and Jonas Reinius

**New switching technologies are needed in the access network of third-generation mobile networks to provide a cost-effective transmission of different kinds of services, such as AMR-coded voice and large bandwidth data. The use of ATM and AAL2 switching techniques in the traffic concentration nodes can significantly reduce the need for link capacity in the access network. The most important sources of these savings are the statistical fluctuation of the number of AAL2 connections, the fluctuation of the number of users at a base station due to mobility, and the granularity of the ATM virtual channel cell rate. Ericsson's offering of AAL2 switching technology enables operators to maximize these gains in the WCDMA radio access network. Indeed, in large networks, this technology has the potential to triple the capacity of the transmission link.**

**The authors describe the advantages of AAL2 switching in the WCDMA radio access network. They also include results from a study comparing bandwidth requirements when traffic between node B and the RNC is aggregated either at the ATM layer, by means of switching AAL2 paths using ATM cross-connect, or at the AAL2 layer, by means of dynamically switching AAL2 connections. The authors also describe the general architecture for terminating and switching AAL2 connections in Ericsson's WCDMA RAN node products.**

## Introduction

Third-generation mobile networks offer a wide variety of services, such as voice, circuit-switched data, and packet-switched data at bit rates ranging from a few kbit/s up to 384 kbit/s (eventually up to 2 Mbit/s). In this environment, highly adaptive transfer and switching methods are needed to deliver different kinds of services in a cost-effective and high-quality fashion. This applies to both the

- radio network layer, which is responsible for transferring data over the WCDMA air interface; and
- transport network layer, which is responsible for transferring data between the nodes (node B and RNC) of the radio access network.

As specified by the Third-generation Partnership Project (3GPP), the transport network layer for the WCDMA radio access network (RAN) is to use ATM transport network technology and protocols. ATM adaptation layer type 2 (AAL2) technology is used for the dominant part of data transfer.

The AAL2 protocol enables several user (radio network layer) connections to be multiplexed flexibly and efficiently on a common ATM virtual channel connection (VCC) between two nodes. The use of AAL2 switching in intermediate nodes has the potential to yield significant statistical multiplexing gains on transmission links that carry aggregated traffic for multiple nodes without loss of control over the quality of service of individual connections.

## WCDMA RAN—transport network architecture and protocols

### WCDMA RAN

Figure 1 gives a schematic view of a WCDMA network, which consists of user equipment (UE), the WCDMA terrestrial radio access network (WCDMA RAN), and the core network.

The WCDMA RAN handles all tasks that relate to radio access control, such as radio resource management and handover control. The core network, which is the backbone of WCDMA, connects the access network to external networks (PSTN, Internet). The user equipment (mobile terminal or station) is connected to radio base stations (node B) over the WCDMA air interface (*Iu*). During soft handover, one UE can communicate with several node Bs simultaneously.

According to the WCDMA RAN specifications drafted by the 3GPP, all radio network functions and protocols are separate from the functions and protocols in the transport network layer. The transport network layer provides data and signaling bear-

**BOX A, TERMS AND ABBREVIATIONS**

| | |
|---|---|
| 3GPP | Third-generation Partnership Project |
| AAL2 | ATM adaptation layer type 2 |
| AMR | Adaptive multirate (voice codec) |
| ATM | Asynchronous transfer mode |
| CAC | Connection admission control (algorithm) |
| CBR | Constant bit rate |
| CCH | Common transport channel |
| CID | Connection identifier |
| CN | Core network |
| CNA | Concentration node area |
| CPP | Connectivity packet platform (formerly called Cello packet platform) |
| CPS | Common-part sub-layer (packet) |
| CS 64 | Circuit-switched data at 64 kbit/s |
| DCCH | Dedicated control channel |
| DCH | Dedicated transport channel |
| DRNC | Drift RNC |
| E1 | ETSI 2 Mbit/s line interface |
| GoS | Grade of service |
| Iu | Core network-to-radio network interface (3GPP) |
| Iub | Node B-RNC interface (3GPP) |
| Iur | RNC-RNC interface (3GPP) |
| LAC | Link admission control |
| MAC | Medium access control |
| Node B | Radio base station, RBS |
| O&M | Operation and maintenance |
| PS 64 | Packet-switched data at 64 kbit/s |
| PS 384 | Packet-switched data at 384 kbit/s |
| PSTN | Public switched telephone network |
| Q.2630 | ITU AAL2 signaling protocol |
| QoS | Quality of service |
| RAB | Radio access bearer |
| RAN | Radio access network |
| RLC | Radio link control |
| RNC | Radio network controller |
| RXI | CPP-based aggregation node |
| SDH | Synchronous digital hierarchy |
| SL1, 2, 3 | Switching level one, two, three |
| SRNC | Serving RNC |
| STM | Synchronous transfer mode |
| TTI | Transmission time interval |
| UE | User equipment |
| UP | User plane |
| VC | Virtual channel |
| VCC | Virtual channel connection |
| VCI | Virtual channel identifier |
| VPI | Virtual path identifier |
| WCDMA | Wideband code-division multiple access |

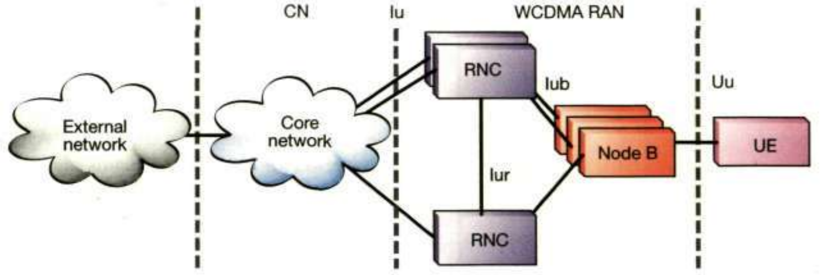



Figure 1
Schematic view of a WCDMA network.

ers for the radio network application protocols between RAN nodes, and includes transport network control-plane functions for establishing and releasing such bearers when instructed to do so by the radio network layer.

The initial WCDMA RAN specifications stipulate that the transport network layer must be based on ATM and AAL2 technology. However, Release 5 of the 3GPP specifications also includes the option of an IP-based transport network.

The focus of this article is on the design of ATM- and AAL2-based transport networks with particular emphasis on the *Iub* interface between the RNC and node B.

### AAL2 at the *Iub* interface

Figure 2 shows the ATM and AAL2-based protocol stack at the *Iub* interface for transferring data streams on common transport channels (CCH) and dedicated transport channels (DCH) to the air interface.

The retransmission mechanism of the radio link control (RLC) protocol ensures reliable transmission of loss-sensitive traffic over the air interface. The RLC protocol is used by signaling radio bearers and by radio bearers for packet-switched data services, but not by radio bearers for circuit-switched services.

The medium access control (MAC) protocol forms sets of transport blocks in the air interface and schedules them according to the timing requirements of WCDMA. Each scheduled period, called a transmission time interval (TTI), is 10 ms in length or multiples thereof.

WCDMA radio connections, or radio access bearers (RAB), have bit rate values between 8 and 384 kbit/s. The size of the MAC transport block sets and length of the TTI are RAB-specific.

For data transfer over the *Iub* interface, the MAC transport block sets are encapsulated into *Iub* frames according to the *Iub* user-plane (UP) protocol for CCH or DCH data streams. Each *Iub* user-plane data stream needs a separate transport network connection between the RNC and node B. The transport network thus establishes one AAL2 connection for each data stream. In Figure 2, the AAL2 switch (optional) is used for building aggregating transport networks.

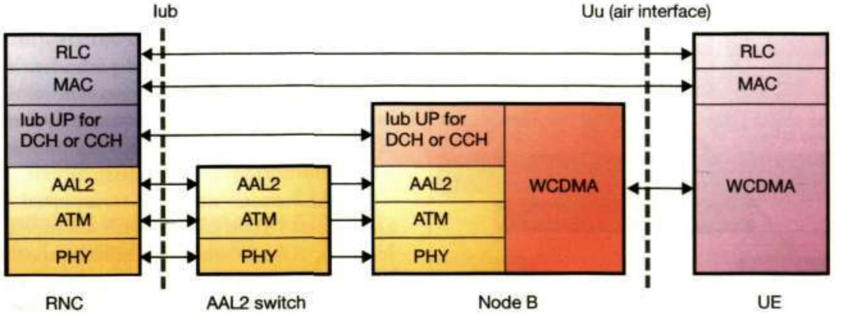



Figure 2
User-plane data transfer between the RNC and node B.

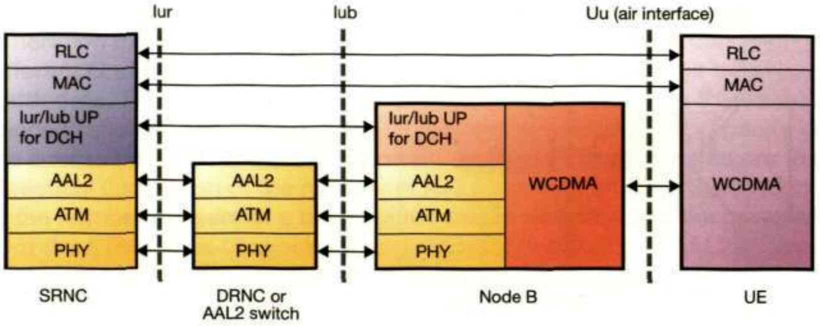



**Figure 3**
**User-plane data transfer between the SRNC and node B.**

## AAL2 at the *Iur* interface

Mobile users sometimes move from radio cells controlled by a serving RNC (SRNC) to radio cells controlled by another RNC, designated drift RNC (DRNC). The *Iur* interface between the RNCs allows the SRNC to maintain contact with mobile users connected via the air interface to one or more cells controlled by another RNC. The user-plane protocol for the DCH data streams is established between the SRNC and node B. If the DRNC incorporates AAL2 switching, an AAL2 layer connection can be established from the SRNC to the node B—that is, without AAL2 connection termination in the DRNC—minimizing the transfer delays via the DRNC. This is particularly important for DCH data streams, which have strict timing requirements for soft handover. If an AAL2 switching network is built to interconnect multiple RNCs and node Bs, then every AAL2 connection for DCH data streams can be set up directly between the SRNC and node B without passing the DRNC. This configuration further reduces transmission costs. The AAL2 control plane (not shown in Figure 3) is terminated in every AAL2 switching node.

User frames are segmented and packed into AAL2 common-part sub-layer (CPS) packets, which are multiplexed into ATM cells (Figure 4). The AAL2 payload can vary in length (up to 45 bytes). The AAL2 header is 3 bytes in length. All ATM cells are 53 bytes in length, including a 5-byte header.

Thanks to AAL2 multiplexing, the AAL2 packets from several AAL2 connections can be transported on one ATM virtual channel connection (VCC). Each ATM cell on the VCC can carry AAL2 packets from different AAL2 connections. The connection identifier (CID) field in each AAL2 packet header identifies the AAL2 connection to which the packet belongs, much the same as the virtual path identifier (VPI) and virtual channel identifier (VCI) fields in the ATM cell header identify the ATM virtual channel connection. [1,2]

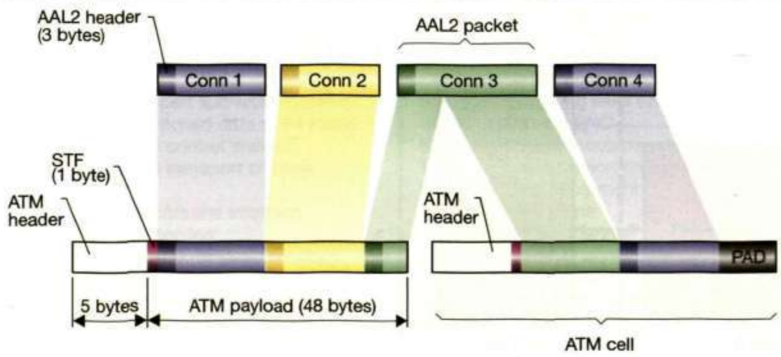
## QoS requirements and admission control

The WCDMA RAN transport layer services must meet stringent quality of service (QoS) requirements. The most important measure of QoS performance in the *Iub* and *Iur* interfaces is maximum packet delay.[3]

To satisfy QoS requirements, AAL2 connection admission control (CAC) is executed before a new AAL2 connection is set up in the system. Connection admission decisions are based on the traffic descriptors and QoS requirements assigned to the connections. The AAL2 admission control procedure allocates bandwidth resources (from available virtual channel and path identifier resources) to AAL2 connections in the transport network. If the requisite amount of resources is not available to accommodate a new connection, it is rejected.

If AAL2 connections are transported in end-to-end virtual circuits with resource allocation, AAL2 connection administration control is only executed at the end points of the virtual circuits (node B and RNC). How-

**Figure 4**
**Assembly of ATM cells.**



ever, if the resources along the path of an AAL2 connection are not allocated end-to-end, the CAC decisions are replaced by or based on hop-by-hop link admission control (LAC) decisions at every AAL2 switch along the path.

## Transport network functions

### Node types

The Ericsson WCDMA RAN system is composed of three kinds of traffic-handling nodes:

- Different versions of node B are available for indoor and outdoor placement and to satisfy different needs for the air interface and transport network capacity. One node B can be configured to serve as a transport network hub using ATM cross-connect and AAL2 switching techniques to aggregate traffic to and from other node Bs.
- The radio network controller (RNC) is a modular multi-subrack node. It is available in various sizes to satisfy different capacity needs.
- The RXI is a transport network node that provides ATM cross-connect, AAL2 switching, and IP router services. This fault-tolerant node is a single-subrack design with numerous interface options and a high-capacity switch core.

The WCDMA RAN system also includes various other nodes not described in this article for operation and maintenance (O&M) support.

### The system platform

All of Ericsson's WCDMA RAN nodes are based on the same carrier-class technology—the connectivity packet platform (CPP, formerly called Cello packet platform). Modular and robust in design, CPP is is characterized by a multiprocessor control system with multiple processor levels, and its use of cell-switching technology to internally interconnect all types of processor boards, external interface boards and application-specific boards. CPP also includes functionality for terminating and switching ATM and AAL2 connections and for terminating and routing IP traffic.[4]

### Switching and termination of ATM and AAL2 connections in CPP

The CPP solution for terminating and switching ATM and AAL2 traffic is at the heart of Ericsson's ATM and AAL2 transport solutions. The node function that provides the through-connection of an ATM virtual channel connection is called the ATM VC cross-connect. Similarly, the node function that provides the through-connection of an AAL2 connection is denoted AAL2 switching.

The 3GPP does not specify how ATM layer connections are to be established and released in the WCDMA radio access network. Ordinarily, permanent virtual channel or virtual path connections are configured using network management actions. In the 3GPP specifications, the establishment and release of AAL2 connections is to be controlled dynamically and in real time by user requests—that is, by the functions of the radio network layer. The AAL2 connections in the WCDMA radio access network are controlled by Q.2630 signaling between the RNC and node B. This signaling can thus be used for setting up connections in a switching transport network between the node B and RNC. The network can be built up of multiple CPP nodes—for example, a tree structure of node Bs combined with pure transport aggregating nodes, such as the Ericsson RXI820 (Figure 5).

The internal cell-switching architecture of the node allows the terminating function of each ATM VCC to be distributed to the processor board or application-specific de-

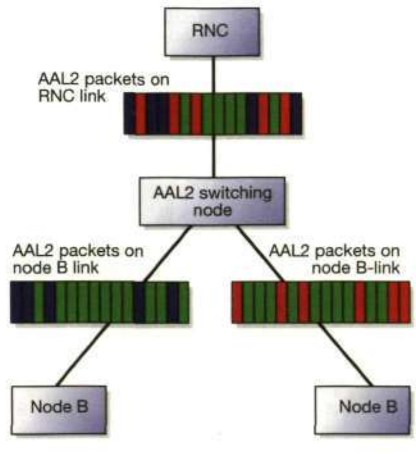



Figure 5
AAL2 switching network.

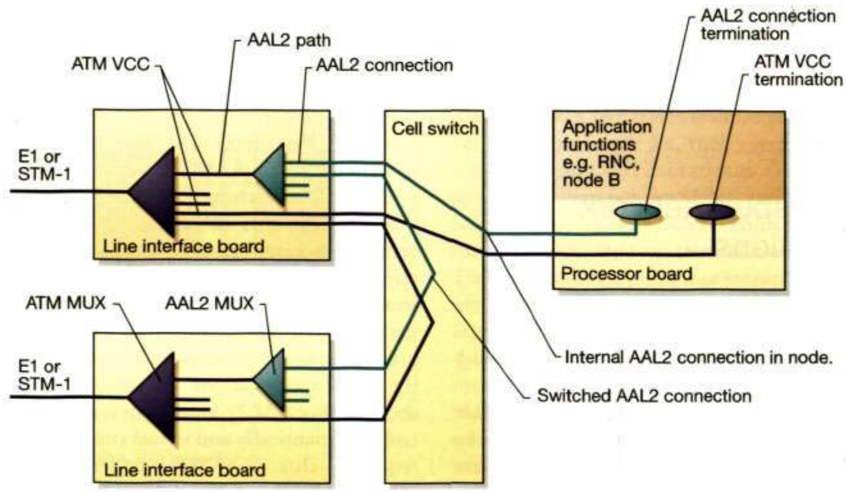



Figure 6
Switching and termination of ATM virtual channel and AAL2 connections in CPP nodes.

vice board on which the application function that uses the connection resides. The ATM line interface boards thus forward ATM cells in either direction between the external line interface and cell switch. The cell switch in CPP transfers ATM cells to and from connection-terminating boards in the node, or to and from external interface boards for cross-connected ATM VCCs.

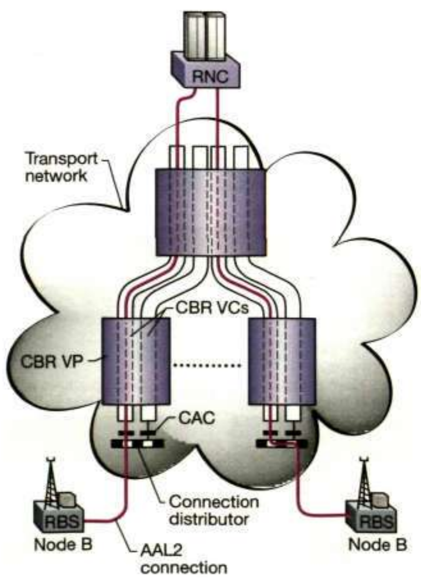



Figure 7
VC-CC model.

Each ATM VCC used by an AAL2 path is terminated by an AAL2 multiplexer function (located on the line interface board) that handles the AAL2 CPS layer, multiplexing and demultiplexing the AAL2 packets to and from ATM cells on the AAL2 path (an ATM VCC, see Figure 6).

For AAL2 connections that terminate within the node, each AAL2 packet is carried via the cell switch directly between the line interface board and the application board that terminates the AAL2 connection.

By contrast, for AAL2 connections that are switched through the node, each AAL2 packet is forwarded via the cell switch directly between the incoming and outgoing line interface boards.

AAL2 packets are switched by hardware on the line interface boards and via the high-capacity cell switch in the same way as ATM cells are switched. Therefore, every traffic-handling RAN node based on CPP technology can efficiently perform switching within the AAL2 layer.

## WCDMA RAN transport network topologies and switching alternatives

Although it is possible to connect a node B to its RNC via a direct, physical point-to-point connection, more commonly an *Iub* connection is established via one or more intermediate aggregation nodes. Connections from multiple node Bs can, in this way, be multiplexed onto the same physical link interface to the RNC.

The basic methods of multiplexing and concentrating traffic in the WCDMA RAN transport network are

- physical-layer multiplexing, using SDH network technology—one STM-1 interface (155 Mbit/s) to the RNC can multiplex, for example, 63 E1 (2 Mbit/s) physical-layer connections to as many node Bs;
- ATM VP or virtual channel cross-connect, using ATM network technology—one STM-1 interface to the RNC can multiplex several virtual channels representing ATM layer connections to many node Bs. The number of VCCs is the same at the RNC interface as the aggregated number of VCCs at the node B interfaces; and
- AAL2 switching, using AAL2 network technology—one STM-1 interface to the RNC can multiplex AAL2 connections to multiple node Bs on a common group of AAL2 paths between the RNC and an intermediate node with AAL2 switching capability. Other AAL2 paths are established between the intermediate node and each node B. The AAL2 switching method is combined with ATM VC cross-connect in the intermediate node of end-to-end ATM VCCs between the RNC and each node B; for example, for signaling and O&M access.

These methods are typically combined—that is, AAL2 switching is introduced on top of ATM cross-connect, which is introduced on top of SDH multiplexing.

To accommodate AAL2 switching in intermediate nodes, resources must be allocated to process signaling for the set-up and release of AAL2 connection and for multiplexing and demultiplexing the AAL2 user-plane.

Compared to an intermediate node, which merely cross-connects AAL2 path VCCs, each AAL2 switching node introduces some delay during connection set-up and transport of the user-plane. The network designer must weigh these costs against possible savings in transmission capacity and network management, and decide to what extent AAL2 switching can be employed.

We have studied the gains in transmission capacity from AAL2 switching at different aggregation levels for *Iub* traffic, comparing two cases of network dimensioning:

- VC-CC—use of ATM VC cross-connect of AAL2 path VCCs in aggregation nodes (Figure 7).
- AAL2—dynamic switching of AAL2 connections between multiple downlink AAL2 paths and fewer uplink AAL2 paths in aggregation nodes (Figure 8).

All AAL2 paths are assumed to be configured as constant bit rate (CBR) virtual channels with a fixed, guaranteed capacity. The connection admission control function, which operates on each AAL2 path, needs to know the total capacity of the AAL2 path to calculate the number of different kinds of AAL2 connections that can be allowed on each AAL2 path while maintaining quality of service for every connection.

## Benefits of AAL2 switching on the *Iub* interface

### Evaluating the performance of AAL2 switching

To evaluate the performance of AAL2 switching, we used a fast and accurate CAC algorithm that takes into account the properties of traffic across the *Iub* interface.[5] The transport network layer grade-of-service (GoS) requirement of each RAB type is met if the blocking probability of its connection remains below a given threshold, for example, 0.3% for voice. Besides the offered traffic (measured in Erlang), the blocking prob-

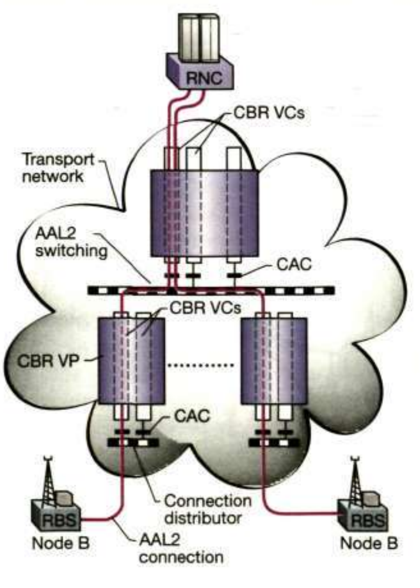



**Figure 8**
**AAL2 switching model.**

**TABLE 1, CONSIDERED TRAFFIC MIX, USER LOAD IN MERLANG AND GOS REQUIREMENT**

| mErlang per user | Standard | Data-oriented | Contains PS 384 | Target GoS (%) |
|---|---|---|---|---|
| Voice | 20.25 | 17.00 | 25.00 | 0.3 |
| CS 64 | 2.25 | 1.00 | - | 0.3 |
| PS 64 | 3.30 | 5.00 | 1.00 | 0.7 |
| PS 384 | - | - | 0.04 | 4.0 |

abilities also depend on the admission control algorithm, and on the number of available AAL2 paths (ATM VPs) between the two nodes.

The connections were generated randomly in a simulator, and the packet-level traffic descriptors were attributes of the generated connections. When a new connection was generated in the simulator, the CAC algorithms executed in the appropriate nodes in the access network, and we measured the blocking probabilities for each service.

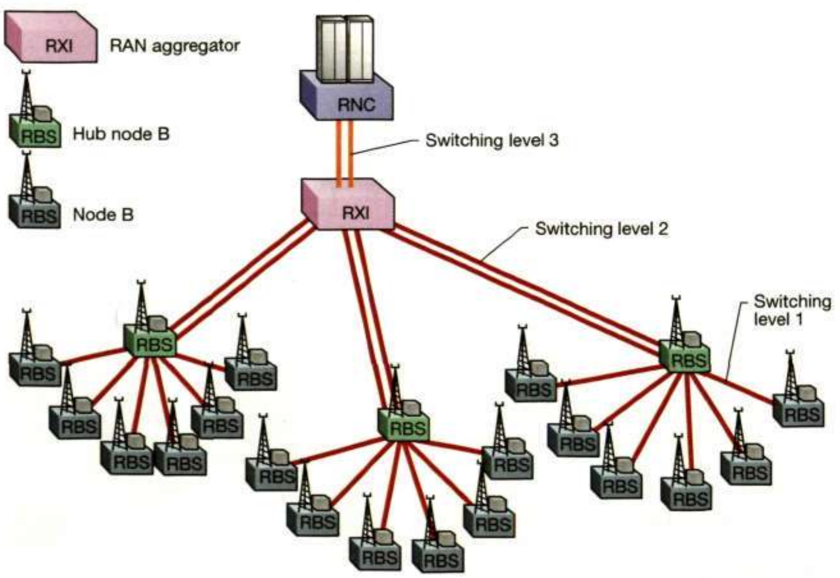
### Traffic parameters

During the simulation, different RAB types were considered for the following services: AMR-coded voice, circuit-switched data at 64 kbit/s (CS 64), packet-switched data at 64 kbit/s (PS 64) and packet-switched data at 384 kbit/s (PS 384). The evaluation also took into account all common channels in a cell and a dedicated control channel (DCCH) connection for each RAB.

We ran simulations for different kinds of traffic mixes (Table 1). The results represent a standard mix of voice (12.2 kbit/s AMR-coded), CS 64 and PS 64. Since many operators do not intend to provide PS 384 bearers when network load is heavy, it was relevant to study traffic mixes that excluded this rate. The results from the other traffic mixes also favored AAL2 switching over VC cross-connect.

For each *Iub* interface, about 200 kbit/s was allocated for non-AAL2 control-plane and O&M signaling.

Figure 9
Tree topology of the WCDMA RAN.



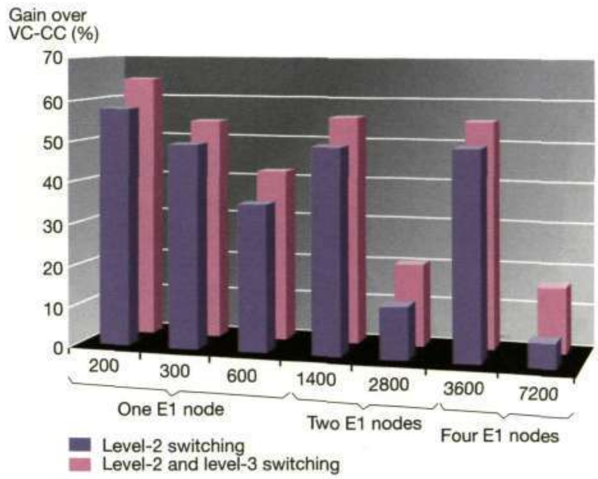



**Figure 10**
**Reduced need for capacity for different number of users and switching layers in the 3x6 topology.**

Note: While the gains from AAL2 switching are typical, the results apply to a specific traffic mix. The actual gains for other traffic volumes, mixes of voice and data, and other activity factors for voice and packet data might vary.

### Statistical gain at different traffic loads

We obtained the numerical results by simulating the network at the connection level.

*Low traffic volume*

Compared to VC-CC switching, the greatest reduction in bandwidth using AAL2 switching can be expected when traffic is light—for example, when only a small part of the allocated bandwidth of the VCs is used.

Let us consider a tree network topology with three AAL2 switching nodes at switching level 2 (SL2), and six node Bs connected to each concentration node (Figure 9). We call this topology the 3x6 topology. Initially, the link capacity at the lowest level is one E1 per node B. The number of users is less than 600 per node B (600 is the maximum number, assuming a standard or data-oriented mix).

For VC-CC switching, the required bandwidth is 14 Mbit/s for a switching node in SL2, and 42 Mbit/s for a switching node in SL3.

We next increased the number of users served by a node B. Obviously, at some point, as the number of users grows, more capacity is needed to connect node B. Figure 10 shows how AAL2 switching reduces the need for capacity in the link compared to VC-CC switching at SL2 and SL3 for different numbers of users per node B using the standard traffic mix. When the number of users exceeds 600, two E1 access links are used. Likewise, when the number exceeds 2,800, four E1 access links are used.

The gain in capacity from using AAL2 switching is calculated as follows:

$$\text{Gain} = (C_{VC\text{-}CC} - C_{AAL2}) / C_{VC\text{-}CC}$$

where CVC-CC is the entire link capacity (aggregated capacity at the considered level) needed for VC-CC, and CAAL2 is the link capacity needed for AAL2 switching.

As can be seen, applying AAL2 switching in SL2 reduces the consumption of link capacity by 35-60%. The gain in capacity obtained from AAL2 switching is especially high (around 60%) when the use of SL1 links is low. The gain is even greater (up to 65%) at SL3.

Thanks to the large gain in capacity from AAL2 switching, the operator can install less capacity at SL2 and SL3 when first introducing service, and later upgrade the link capacity between switching nodes.

*Fully loaded system*

Operators generally try to avoid loading the network to its limit. Nevertheless, they do need to determine the capacity limit and in-

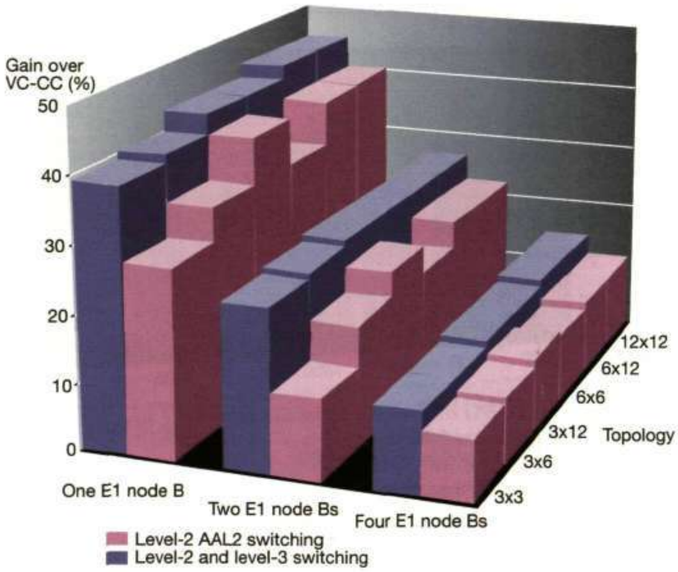



**Figure 11**
**Fully loaded system. Gain in level-2 and level-3 link capacity from AAL2 switching.**

vestigate traffic cases close to this limit. QoS problems are more likely to occur when load is heavy. Figure 11 shows the gain in capacity for the different network sizes with up to twelve switching nodes in the second level, twelve node Bs connected to each switching node (12x12 topology), and a fully loaded system.

Compared to VC-CC switching, the gain in capacity increases as more node Bs are added per SL2 switching node. Due to a homogenous distribution of traffic among node Bs, the gain from AAL2 switching at SL2 is the same for configurations with the same number of node Bs per switching node (for example, 3x12, 6x12 and 12x12). By

**TABLE 2, USER DISTRIBUTION THROUGHOUT THE DAY**

| Users per node B | CNA1 | CNA2 | CNA3 |
|---|---|---|---|
| Morning | 1,400 | 2,800 | 2,800 |
| Mid-day | 2,800 | 1,400 | 2,800 |

applying AAL2 switching at L2 and L3, the gain increases slightly as a function of the number of switching nodes.

The 3x6 topology used two E1s per node B (Figure 11): An 18 percent gain in capacity was obtained when AAL2 switching was applied at level 2, and 25%, when applied at levels 2 and 3.

### Gain from changing traffic distribution

In general, the distribution of traffic among node Bs is not homogenous. A concentrating switching node aggregates the traffic of several node Bs. Therefore each switching node has an associated serving area, which we call the concentration node area (CNA).

Let us assume that a CNA covers an office area and a residential area. Applying VC-CC switching, we attempt to establish as many VC connections between node Bs and the RNC as are needed to serve the sum of the maximum traffic of each node B. In this case, it does not matter that peak traffic occurs at different hours in the office and residential areas.

However, AAL2 switching allows the concentrated link capacity to be dimensioned for the sum of the actual traffic in the CNA.

Consider a 3x6 topology, in which the node Bs are connected by two E1 links. The maximum number of users in the switching node areas is 2,800 per node B assuming a standard mix of traffic. Let us also assume that due to user mobility, the number of users per node B changes over time (Table 2). Compared to VC-CC switching, the gain from AAL2 switching is 26% on SL1 and 32% on SL2.

**TABLE 3, COMPARISON OF SWITCHING ALTERNATIVES**

| | VC-CC | AAL2 |
|---|---|---|
| Statistical multiplexing capacity reduction | No | High (7 to 65%) |
| Reduction if traffic distribution changes | No | Yes (26 to 32%) |
| QoS guarantee | Yes, with CAC for each AAL2 path configuration | Yes, with CAC for each connection setup |
| Number of VCs minimized | No | Yes |

## Conclusion

The performance of AAL2 switching is superior to that of VC-CC switching. In several network scenarios that use AAL2 switching, the increased cost of processing AAL2 signaling is more than compensated for by significantly increased efficiency in the transmission network, and reduced costs of transmission.

The savings are greater when there is little traffic in the network—precisely when the network operator needs most to keep costs down. AAL2 switching also considerably reduces the need for link capacity in a fully loaded network with traffic concentration.

By applying AAL2 switching, operators can significantly reduce the need for link capacity since the network can adapt to changes in traffic levels.

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# Microwave transmission in mobile networks

Aldo Bolle and Andrea Nascimbene

**Microwave links became an enormous success with the roll-out of second-generation mobile networks. With close to 500,000 units delivered to date, the Ericsson family of MINI-LINK microwave products has an important role in mobile operator networks. Now, the advent of third-generation mobile networks is starting a new wave of deployment characterized by cost-effective and flexible roll-out, and short site-to-site distance. Moreover, we are seeing a shift in focus from plain point-to-point bit transport to a network view with optimized site solutions.**

**The authors address the launch of Ericsson's microwave solution for transmission in current second-generation and imminent third-generation mobile networks, showing how combined use of the point-to-multipoint and point-to-point technologies provides the most cost-effective and spectrum-efficient solution.**

The inherent reliability and cost-effectiveness of microwave technology have been given a dominant role in connecting mobile radio base stations (RBS). The roll-out of packet-data and third-generation mobile networks fundamentally changes the traffic demands on transmission systems. Consequently, new microwave transmission techniques and solutions are required.

With the continuous growth of mobile subscribers and mobile data communication, operators need enhanced microwave transmission systems. In particular, enhanced features are needed to handle changing traffic patterns efficiently, to offer increased capacity, and to make optimum use of radio spectrum.

To achieve profitability, operators must have flexibility and be able to respond quickly to dynamic market conditions. These requirements make microwave, with its ease of implementation, ideal for access transmission.

Today, 60% of all second-generation RBSs are connected via microwave technology. As voice and data traffic increases in mobile networks, PDH-based point-to-point microwave solutions can be complemented with ATM-based point-to-multipoint solutions and SDH equipment to create a unified, fully integrated and cost-effective transmission solution that gives operators the best network control and most profitable operation.

## MINI-LINK portfolio

The MINI-LINK portfolio includes solutions for point-to-point as well as for point-to-multipoint operation. Terminals and smart nodes (Figure 1) are used for implementing the building blocks in a network.

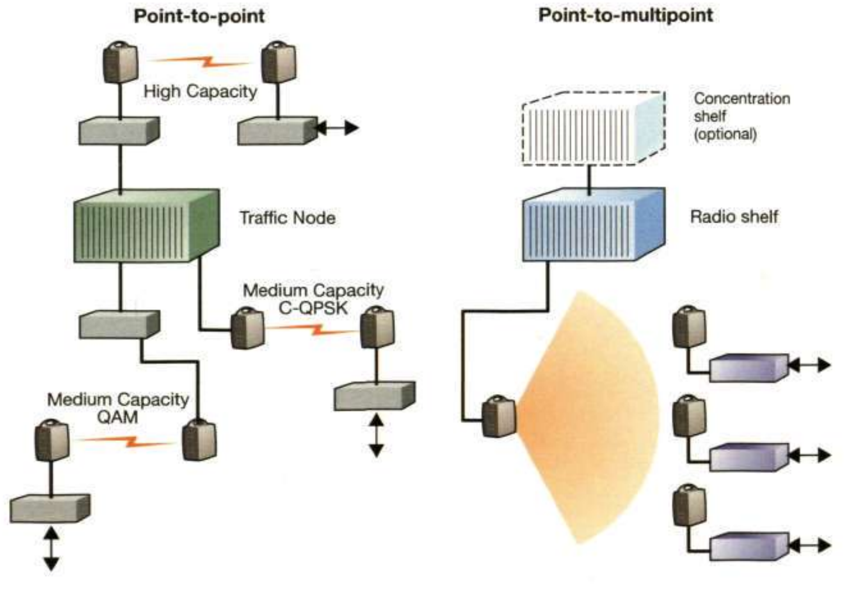



**Figure 1**
**The MINI-LINK portfolio.**

**MINI-LINK point-to-point**

Ericsson's microwave point-to-point portfolio consists of MINI-LINK Medium Capacity and High Capacity terminals, and the MINI-LINK Traffic Node (Figures 2-3). Depending on the range and capacity to be implemented, the MINI-LINK portfolio offers frequencies ranging from 7 to 38 GHz, for hop lengths of several tens of kilometers to just a few kilometers, and transmission capacities of up to 155 Mbit/s. Constant envelop offset – quadrature phase-shift keying (C-QPSK) and quadrature amplitude modulation (QAM) schemes are available for the terminal configurations. The MINI-LINK Traffic Node, which is a smart node for point-to-point operation, has been optimized for the aggregation nodes in the network, thus providing the ideal capacity and functionality to solve transmission needs. It complements the terminals with the additional features needed to provide a complete and efficient site and network solution.

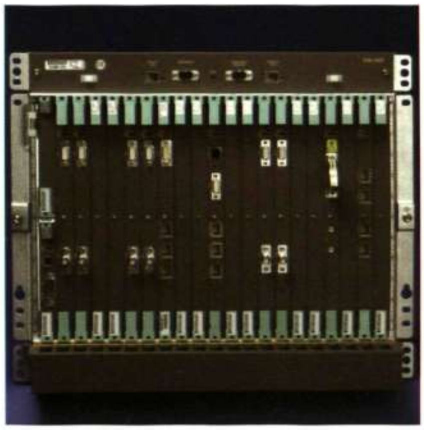


Figure 2
MINI-LINK Traffic Node.

**BOX A, TERMS AND ABBREVIATIONS**

| | | | |
|---|---|---|---|
| AAL2 | ATM adaptation layer type 2 | QAM | Quadrature amplitude modulation |
| ATM | Asynchronous transfer mode | RAN | Radio access network |
| CPP | Connectivity packet platform | RBS | Radio base station |
| C-QPSK | Constant envelop offset – quadrature phase-shift keying | SDH | Synchronous digital hierarchy |
| E1/E2/E3 | ETSI digital multiplexing stage | SNMP | Simple network management protocol |
| IP | Internet protocol | STM-1 | Synchronous transport module level 1 |
| LAN | Local area network | T1/T2 | ANSI digital multiplexing stages |
| MIB | Management information base | VC | Virtual container |
| OC-3 | ANSI digital multiplexing stage | xDSL | Digital subscriber line |
| PDH | Plesiochronous digital hierarchy | | |

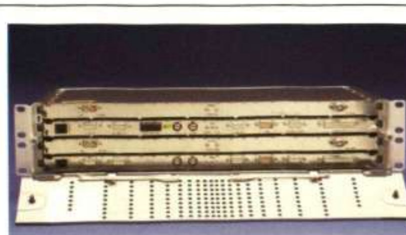


Figure 3
MINI-LINK Medium Capacity terminal (left) and MINI-LINK High Capacity terminal (right).

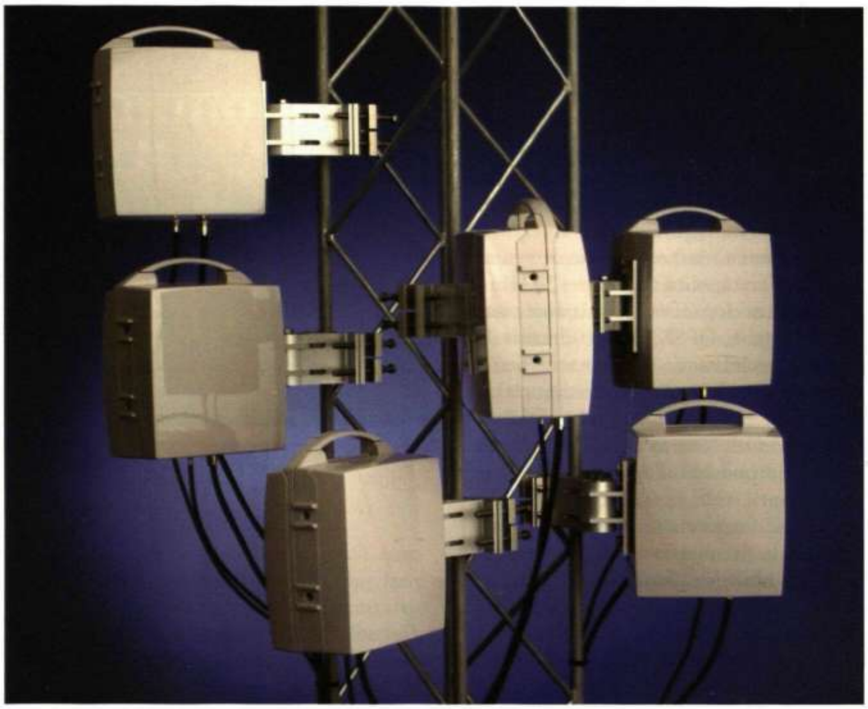


Figure 4
MINI-LINK outdoor radios.

### MINI-LINK point-to-multipoint

The MINI-LINK point-to-multipoint system (Figure 5) provides 37.5 Mbit/s data transfer per sector. Each sector can be 90° in the standard solution or 180°/360° in the "launch" solution, in accordance with the required capacity and RBS density ratio. The capacity within a sector can be fixed or dynamically allocated to each terminal, allowing, in the latter case, reallocation of capacity within a few milliseconds. The system is thus very suitable for data traffic, both for business access and backhaul in mobile systems. It uses ATM to guarantee different classes of service. E1, ATM (over E1/T1, E3/T3 or STM-1/OC-3) and Ethernet interfaces are available. The system operates on frequencies from 24 to 31 GHz and uses the C-QPSK modulation scheme.

Figure 5
MINI-LINK BAS radio shelf.

### Management system

The third building block in the portfolio is the MINI-LINK Manager (Figure 6), which enables operators to manage a complete MINI-LINK microwave transmission network from a single screen. Network element management provides functionality for managing faults, performance, configurations and security. Together with local craft terminals (LCT) and the element-management functionality embedded in the network elements, the MINI-LINK Manager gives operators the tools they need for efficient and cost-effective operation of a MINI-LINK network.

MINI-LINK Manager has several export interfaces for easy integration into other network-management systems. It can be incorporated into a total management solution for mobile systems, either as part of a complete solution provided by Ericsson or as an integration with an existing management system.

### MINI-LINK features

#### *Bandwidth aggregation*

The point-to-point and point-to-multipoint smart nodes are hub solutions developed to support a large number of sites and future increases in capacity. Being scalable, the smart node enables the aggregation of traffic bandwidth that originates from a large number of end-nodes. At Medium Capacity aggregation nodes, the bandwidth is aggregated into a medium-capacity interface (maximum 34 Mbit/s) Similarly, at High Capacity aggregation nodes, the bandwidth is aggregated into a high-capacity interface (STM-1 or greater). Traffic from the aggregation nodes can be further transmitted either on microwave or optical links.

In a point-to-multipoint system, the air interface is shared among multiple access terminals. The shared media enables multiplexing gains over the air, provided a packet-based infrastructure is employed. MINI-LINK point-to-multipoint is based on ATM end-to-end, which enables multiplexing gains and efficient usage of the bandwidth when second- and third-generation traffic is handled in the aggregation nodes.

#### *Use of spectrum*

Spectrum is a sparse resource. Besides the continuous development of radios in newly allocated frequency bands, some important new features have been introduced in the MINI-LINK portfolio to deal with future shortages of spectrum. To allow the operator to increase transmission capacity within an existing frequency spectrum, higher-order modulation methods (based on 16 and 128 QAM) have been introduced in the MINI-LINK point-to-point portfolio. These new features give the operator additional flexibility in balancing spectrum and power efficiency in the network.

Point-to-multipoint systems (Figure 7) make efficient use of spectrum by

- allocating capacity per ATM cell (ATM granularity gain) instead of on a 2 Mbit/s-basis;
- ATM multiplexing in conjunction with fast dynamic capacity allocation. The network can be "oversubscribed" in terms of number of registered users while still maintaining QoS; and
- delivering unused access capacity to other services, such as wireless LAN access points or business access users, based on the diversity gain of the daily traffic profile (daily profile gain), since the busy hours for residential users generally differ from those of business users.

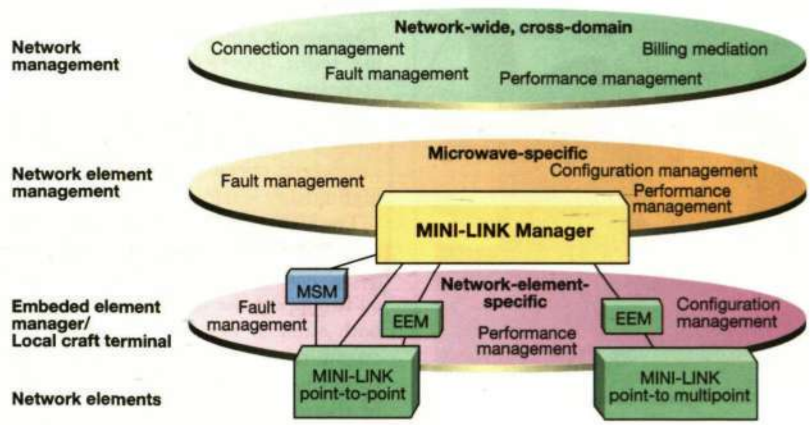



**Figure 6**
**MINI-LINK Manager—its role in network management.**

**Figure 7**
**Aggregation gain. The diagram shows the aggregated link capacity required by multiple base stations per base station. The red line indicates aggregating link capacities. The yellow line represents peak load capacities, and the blue line, average traffic loads. The aggregation gain increases as the number of base stations connected in the same sector increases.**

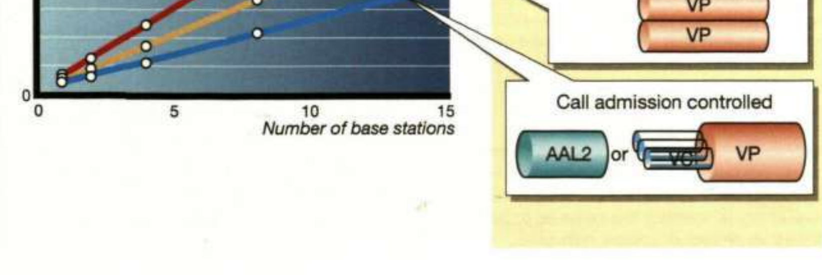


Figure 8
Installing MINI-LINK.

**BOX B, PLANNING MICROWAVE TRANSMISSION, AVAILABILITY AND QUALITY**

Traditionally, operators have deployed mobile backhaul networks using a combination of point-to-point microwave and leased lines. A determinant when choosing between microwave and leased lines is the individual operator's needs in terms of network control and transmission quality.

Typical leased-line contracts have often guaranteed availability figures around 98.7%, which corresponds to a potential of four or five days downtime per year. Microwave networks (which are often used to relink the entire connection between the end-RBSs and the switch site) are dimensioned for 99.95% availability or better, which corresponds to four hours or less of downtime per year.

In conclusion, the availability of a microwave network is very much a planning issue. By selecting high-quality products in combination with proper network planning, availability is normally the same as or better than that of fiber or copper networks.

*Protection*

The operator's most important asset is end-user traffic. If service delivery is not reliable, end-users will change service providers. High-quality equipment that is complemented with additional protection mechanisms gives operators a means of delivering high-quality services.

The MINI-LINK products are protected against equipment failure and radio propagation anomalies. All hardware is duplicated to support the configurations on one or both sides of the radio connection. The transmitting equipment can be configured to operate in hot standby or working standby transmission mode.

The MINI-LINK Traffic Node adds yet another level of protection—network or ring protection. This functionality enables the operator to build reliable ring structures based on any microwave capacity up to 155 Mbit/s. These protection mechanisms work at the E1/T1 level, protecting every or pin-pointed E1/T1s within the total payload.

The Traffic Node solution also includes line-protection mechanisms without the duplication of hardware. Instead, the E1/T1s to be protected are routed into two separate ports on the same interface board.

*Ease of installation and visual impact*

Speed of installation is always a business consideration, especially during the roll-out of third-generation networks in Europe. Microwave is less costly and time-consuming to deploy than copper leased lines. The MINI-LINK portfolio has been optimized for simple installation with a compact, easy-to-carry outdoor unit (Figure 8). The single-cable interface between the indoor and outdoor unit, and the single-bolt alignment fixture are well known. The point-to-multipoint system is even less complex and therefore faster to install, since only one end of the link has to be installed. In addition, new base stations or interfaces can be added to the backhaul network configuration, literally in a matter of minutes, minimizing maintenance and upgrade costs.

The point-to-multipoint hub needs only one antenna (and a single cable between outdoor and indoor equipment) per sector, regardless of the number of connected RBSs. This strongly minimizes the visual impact, especially in cities and towns where antenna pollution is an important issue. Moreover, fewer antennas means fewer sites (simpler site acquisition) and reduced installation time and cost.

*Data communication networks*

The Ericsson network solution for transporting operation and maintenance (O&M) information from equipment to the management center is based on IP communication over Ethernet, with a distributed management information base (MIB) architecture.

MINI-LINK provides efficient in-band data communication between end-nodes and aggregation nodes. The MIB is physically located in each network element. Using the simple network management protocol (SNMP), operators can access O&M information in the MIB remotely from a network management system. They can also access the information locally, on site, by means of the local craft terminal. The terminal software can be upgraded remotely from a central location, or locally using a laptop connected to the terminal.

Each MINI-LINK Traffic Node and High Capacity terminal holds its own IP router for extending the data communication network throughout the transmission network, and transporting O&M information on other equipment via external service channels.

## Combined solutions for the mobile transport RAN

In dense areas, point-to-multipoint has clear advantages over point-to-point transmission. As a simple rule of thumb, point-to-multipoint becomes an interesting option when four or five RBSs can be seen from one location. However, the two technologies are, and will be, used in combination. Point-to-point microwave, which is typically deployed in areas with fewer RBSs, can be combined with point-to-multipoint to overcome distances or interference.

The combination of Ericsson's point-to-point and point-to-multipoint product families results in the most cost-optimized and spectrum-efficient solution for second- and third-generation networks (Figure 9).

E1/T1 aggregation via point-to-point links is typically suitable in small hubs where the number of directions (or connected RBSs) is limited and spectrum is not an issue (the required bandwidth is very likely to be a portion of that required to deploy the large hub).

ATM aggregation, typically via point-to-multipoint, is more suitable in large hubs where the number of directions (or connected RBSs) is great and spectrum efficiency is a must (since it determines the size of the frequency blocks required).

The hubs are connected to each other, to the switch site, or both, via point-to-point systems in accordance with the required range, capacity and available spectrum.

### E1/T1 multiplexing nodes

The E1/T1 multiplexing node is the current solution for present-day second-generation networks. In all likelihood, it will also be the most efficient solution for operators who plan to add third-generation services in environments where second-generation traffic will continue to dominate. This is also the typical solution for operators who want to reuse as much of the existing network as possible (by exploiting spare capacity on the microwave links or on STM-1/OC-3 rings). This aggregation strategy might also be justified by the price structure for leased lines. The benefits of a network based on E1/T1 multiplexing nodes are low initial investments and secure upgrade with minimum disturbance to existing traffic.

Figure 9 exemplifies how a combination of point-to-multipoint and point-to-point links can efficiently serve the Medium Capacity and High Capacity aggregation nodes.

The Low Capacity and Medium Capacity aggregation nodes typically handle from two to four radio base stations—that is, from two to four directions. These nodes are generally deployed where RBS density is low and the RBS-to-RBS distance is great.

In the southbound direction (Figure 9), the Medium Capacity aggregation nodes interconnect the end RBSs through MINI-LINK point-to-point; in the northbound direction, the connection can be made via MINI-LINK point-to-multipoint (Low Capacity ATM aggregation nodes) or point-to-point terminals (Medium Capacity E1/T1 aggregation nodes), depending on capacity, protection and range requirements.

Ordinarily, the High Capacity aggregation nodes are located in suburban or urban areas where RBS density is high. During operation, error-free transport over microwave links is guaranteed by large fading margins and forward error correction mechanisms, which make microwave links highly suitable for ATM and IP transport. In these sites point-to-multipoint is likely to connect the end RBSs. Those RBSs that are outside the point-to-multipoint coverage range are connected through point-to-point links.

When E1/T1 traffic is aggregated, the MINI-LINK point-to-multipoint system for second-generation traffic connects to the MINI-LINK Traffic Node through *n*xE1, which, in turn, provides a single STM-1 VC12 interface to the switch site.

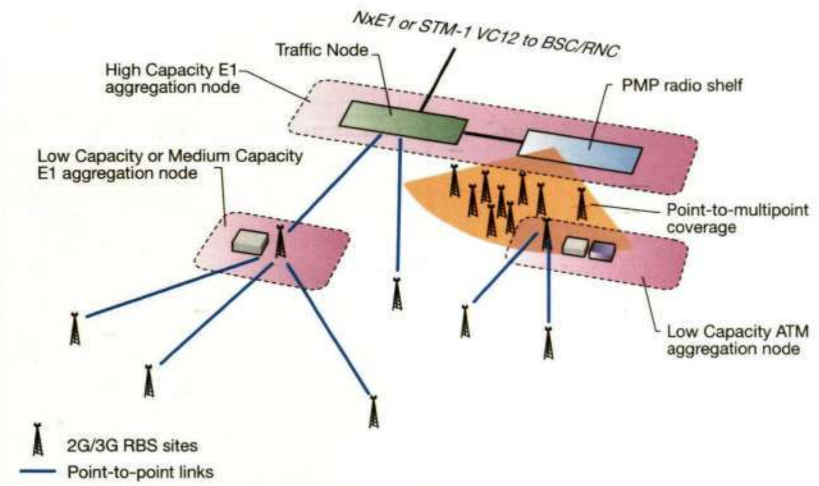



**Figure 9**
**Example of site solutions based on E1 multiplexing and the combining of point-to-multipoint and point-to-point.**

The main drawbacks of the E1/T1 multiplexing solution can be limited expansion and greater long-term cost of operating the network.

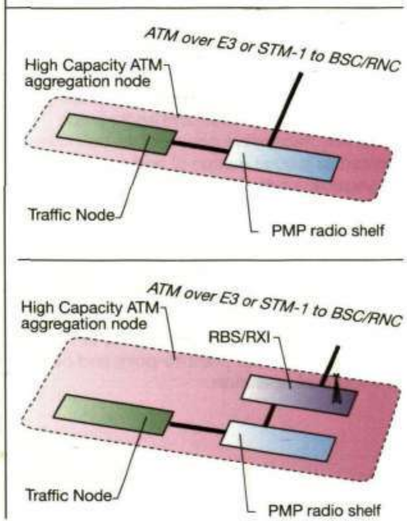
### ATM aggregating nodes

When third-generation traffic dominates over second-generation traffic, ATM aggregating nodes can be used to provide the most cost-effective network solution. Networks based on ATM aggregating nodes are likely to be typical for greenfield operators and for incumbent operators who want to overlay the existing network or to replace existing leased-line connections.

The MINI-LINK point-to-multipoint hub provides port aggregation, aggregating traffic from point-to-multipoint and point-to-point terminals. It also provides a very efficient and cost-effective solution for cellular backhaul applications. It can also aggregate traffic from leased lines and xDSL lines. In the northbound direction, a single ATM-over-STM-1 VC4 interface provides a very clean and cost-effective solution that optimizes backbone capacity, switch site complexity and cost.

This solution can also be used in combination with Ericsson's RBS and RXI products, providing a complete Ericsson mobile and transport network (Figure 10). In

**Figure 10**
**Top: Example of High Capacity aggregation node handling ATM.**
**Bottom: Example of combined CPP and MINI-LINK point-to-multipoint (PMP) radio shelf.**



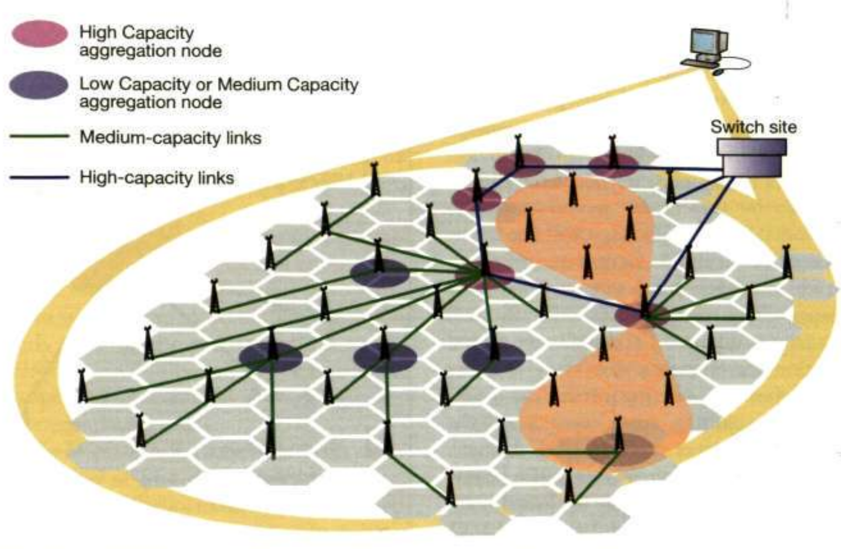



Figure 11
Network architecture.

addition to the benefits of ATM aggregation, the solution brings optimized statistical multiplexing gain, thanks to the AAL2 switching functionality of the connectivity packet platform (CPP, formerly called Cello packet platform). Because ATM virtual-path multiplexing and port aggregation are performed in the MINI-LINK point-to-multipoint radio shelf, the AAL2 functionality is achieved while optimizing costs (no increase in number of boards).

**BOX C, NETWORK ARCHITECTURE**

The use of short-haul microwave radio has evolved from scattered cable replacements to the forming of complete microwave-based transmission networks. The requirements put on the products have shifted from optimization of the terminal or hop level to optimization of the network level. In a microwave network, one can define logical nodes (or physical sites) with distinct characteristics. The logical building blocks are the end-node and aggregation node. Any microwave network can be implemented as a combination of end-nodes and aggregation nodes (Figure 11).

To address the network aspects, Ericsson's products are optimized for the different types of network node. Therefore, the MINI-LINK portfolio comprises compact, cost-effective access terminals and smart nodes that feature advanced traffic routing and multiplexing. The MINI-LINK portfolio includes access terminals and smart nodes for point-to-point and point-to-multipoint operation.

**Typical building blocks of a microwave network**

*End-node*
The end-node is the smallest building block. By definition, it supports transmission in only one direction. In most cases, the capacity of the end-node ranges from 2x2 up to 34 Mbit/s. Ordinarily no redundancy is required at end-node sites and therefore the normal microwave configuration is 1+0. Point-to-point and point-to-multipoint end-nodes are foreseen. The end-node should support traffic interfaces ranging from multiple E1/T1s to Ethernet. Ideally, in a point-to-multipoint system, the end-node will provide an ATM interface for third-generation backhaul, to take better advantage of the shared air interface.

*Low Capacity and Medium Capacity aggregation nodes*
The Low Capacity and Medium Capacity aggregation nodes have a northbound microwave link that carries traffic up to 34 Mbit/s. In the southbound direction these nodes have a limited number of subtended end-nodes.

Ericsson's solution to the Medium Capacity aggregation node has been to design smart, cost-effective Traffic Nodes that can aggregate all traffic from the southbound links into another microwave link in the northbound direction. The solution supports protected and non-protected configurations of the Medium Capacity aggregation node. The solution also supports dropping and insertion of local traffic.

*High Capacity aggregation node*
The High Capacity aggregation node has a northbound transmission link with a traffic capacity of 155 Mbit/s or greater. The northbound media can be either optical or microwave. The topology in the northbound direction can be ring or point-to-point. Since the High Capacity aggregation node supports a considerable amount of traffic, it is assumed that most of the sites will aggregate a substantial number of southbound links. Some end-nodes are directly connected to the High Capacity aggregation node and some are connected through a Medium Capacity aggregation node. Point-to-point, point-to-multipoint and E1/T1 and ATM aggregating sites are supported. The Ericsson solution to the High Capacity aggregation node can be designed to be very compact and cost-effective, as part of an all-microwave solution that supports 155 Mbit/s traffic capacity.

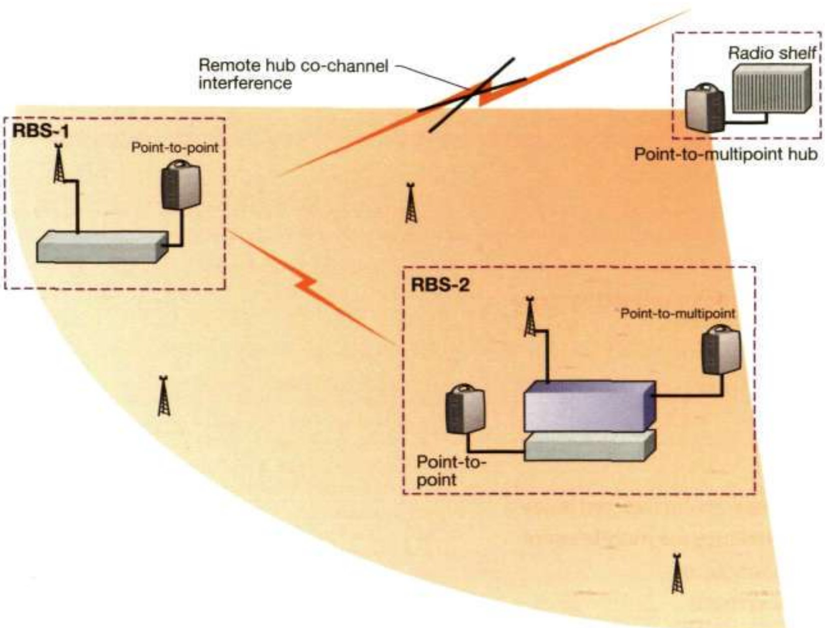



Figure 12
Operators can reuse frequencies by combining point-to-multipoint and point-to-point systems.

## Conclusion

The key issues for efficient support of the mobile network infrastructure are:

- A complete portfolio of point-to-point solutions (any frequency, any capacity, PDH/SDH), explicitly designed for a smart network-oriented approach.
- An ATM-based point-to-multipoint solution that provides a suitable combination of high coverage and high capacity.
- A combination of these technologies to provide the most cost-effective and spectrum-efficient microwave solution.
- An integrated management system for the entire portfolio.
- Proven reliability and large production capability for secure roll-out.

Uniquely, the Ericsson MINI-LINK portfolio can meet all of these requirements.

### BOX D, IMPROVING SPECTRUM EFFICIENCY BY COMBINING POINT-TO-MULTIPOINT AND POINT-TO-POINT SYSTEMS

One fundamental issue in microwave network planning is the efficient use of the frequency spectrum. National authorities and international committees regulate the availability of spectrum. Point-to-point links typically require a license per link, whereas licenses for point-to-multipoint systems are issued as regional or national block allowances. In many cases, operators prefer block licenses since they allow faster planning and deployment of the links.

In point-to-multipoint cellular deployments, a few locations inside the multipoint sector can experience interference from neighboring hubs. However, this effect can be minimized by avoiding reuse of frequencies in neighboring sectors or by combining point-to-multipoint with point-to-point technologies.

In Figure 12, the RBS-1 location is assumed to be affected by co-channel interference from a remote point-to-multipoint hub if connected to the local hub through a point-to-multipoint terminal. If the RBS-1 is instead connected to the RBS-2 location by means of a point-to-point link, the antenna angular discrimination improves the carrier-to-interference ratio and guarantees error-free operation. It is worth noting that the point-to-point link can reuse part of the same point-to-multipoint spectrum, allowing for a very spectrum-efficient solution. Thanks to the combined MINI-LINK point-to-point and point-to-multipoint solution, only a single 28 MHz link is required for the complete network deployment (excluding the spectrum for the northbound connections).

# Previous issues

## No. 2, 2002

Experiences of operating a pre-commercial WCDMA network
RNC3810—Ericsson's first WCDMA radio network controller
CPP—Cello packet platform
Ericsson seamless network
Ericsson's GSM RAN capacity solutions

## No. 1, 2002

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