The success of GSM to date has been nothing short of sensational. What is more, its future continues to hold great promise. However, two important challenges must yet be resolved to make GSM the mobile communications system for the “next billion users” and to guarantee the commercial success of its mobile data services: focus on low total cost of ownership (TCO), and deployment of enhanced GPRS (EGPRS) in every network. In addressing these challenges, GSM transport or backhaul constitutes one very interesting and dynamic area of development.

Background

Transmission to radio base station (RBS) sites accounts for a large part of the cost of operating radio access networks. Where operators have built their own transport networks, transmission also represents substantial investment (Figure 1).

Traditional transmission from RBSs to a base station controller (BSC) is realized using static time-division multiplexing (TDMA) circuits. This technology has not been optimized for efficient transmission of bursty data traffic, however. Nor is it easily adapted to the low-cost transport technologies, such as IP and Ethernet, which are being rolled out over copper, fiber, and microwave networks.

The good news is that recent developments in GSM transport and switching technologies promise to overcome these issues, making GSM suitable to provide services both to low-revenue users and to users of high-speed data services.

Technical overview, Packet Abis

Packet Abis, Ericsson’s collective solution for these developments (Figure 2), includes a new protocol for transferring data over the Abis link. Simply put, from the air interface the solution sends all traffic (voice, data and signaling) in packets over Abis with a minimum of repacking and reformatting. The solution can be used over TDM transport networks as well as with IP or Ethernet transport services. Ericsson’s Packet Abis solution is built around two main features:

- **Abis Optimization**
- **Abis over IP**

**Low TCO using TDM transport networks**

- **Abis Optimization**, which is Ericsson’s solution for delivering Packet Abis over TDM transport networks, saves bandwidth by solely transporting bits that contain data. All other bits (for example, those that were previously used to maintain a constant bit rate to fit the PDH channel format) are no longer inserted.

Ericsson has integrated the **Abis Optimization** solution into its base station subsystem (BSS). The **Abis Optimization** feature is based on a software upgrade of the RBS, and the introduction of a packet gateway (PGW) in the BSC, to terminate the Packet Abis protocol. To save even more bandwidth, one may add a site integration unit (SIU) at RBS sites to exploit statistical multiplexing gains between RBSs.

**Dimensioning example, Abis Optimization**

The number of E1/T1 links required per site with **Abis Optimization** depends on site configurations and traffic mix. In T1 markets, one RBS 2106/2206 with up to 12 TRXs can cover three sectors with only one T1. With “classic” Abis, two T1s would be required for this configuration.

In E1 markets, one E1 can support two RBSs with up to 18 TRXs. For standard base station configurations, this could translate into a savings of up to 50%.

**Low TCO with Packet Abis using IP or Ethernet transport services**

The **Abis over IP** solution enables operators to use IP and Ethernet transport networks to connect RBSs to the BSC and thereby benefit from the lower costs of IP- and Ethernet-based transport services. The solution also opens the door to shared transport with WCDMA and to integrated transport solutions for RBS sites.

The solution is fully interoperable with Ericsson’s other products. At an RBS site, all IP features are implemented in the new STN function, connecting the site to IP or Ethernet transport networks. The STN is a software function that can be implemented in Ericsson’s base stations.

The site transport node is implemented on a family of platforms that have been optimized to fit pico, micro, and macro RBSs. The packet-switched termination unit (PSTU) platform for micro RBSs, for instance, has been completely integrated into Ericsson’s micro RBS.

In macro RBSs, Ericsson has integrated the STN into the site integration unit (SIU), which is designed to serve as a single point of connection that supports common, integrated transport to the RBS site. With the SIU (Figure 3), one can efficiently manage and share backhaul transport for GSM RBSs.

Figure 1

Breakdown of the costs of operating radio access networks.
WCDMA RBSs, and other equipment that connects via IP or Ethernet.

The packet gateway used for Abis Optimization can simultaneously handle IP traffic and traffic from the TDM transport network, and terminate Abis over IP at the BSC site.

**Quadrupling the performance of EDGE without extra transmission**

Many operators who deploy EDGE have deemed it necessary to constrain throughput to match the limitations of available TDM transmission capacity. The classic TDM-based Abis interface has a fixed allocation of transmission timeslots to basic radio channels. Therefore, the subordinate 16kbit/s timeslot on the Abis interface permanently allocated to a traffic channel (TCH) for voice service will never be available to carry EDGE data.

With packet Abis the transport resources make up a common pool that is used by the traffic offered at each moment in time. The new Packet Abis, however, has no such permanent connection. Therefore, E1 or T1 transmission can now offer a multilink point-to-point protocol (MLPPP) bit pipe that may be freely used by every service offered by the RBS until it reaches saturation (congestion). At that point, the BSC dynamically reduces the generated load through its control of mobile terminals.

In many locations, operators have also limited EGPRS to one timeslot, giving subscribers a peak performance of at most 59.2kbit/s. However, by deploying Packet Abis, operators can quadruple the speed at most times of the day without adding transmission capacity, thereby giving users the ability to, say, surf the internet at more than 230kbit/s.

**Synchronization**

To comply with GSM specifications and guarantee proper GSM network function, the RBs must maintain a stable and controlled radio frequency over the air interface. Depending on the type of RBS, the stipulated level of accuracy is 50 or 100ppb.

RBs with traditional TDM-based Abis are synchronized to timing provided by the transport network layer-1 clock rate. TDM networks are typically synchronized to an accuracy of 16ppb, which with added wander and a holdover budget, is well within the requirements of the air interface.

With Abis over IP, however, one cannot assume that the transport network carries timing for synchronization on layer-1. Ethernet, for example, does not currently support layer-1 timing for RBS synchronization. Other means must thus be used to synchronize RBs. Operators who employ Abis over IP can synchronize their radio base stations using timing information from:
- a GPS receiver at the RBS site; or
- the IP network.

**GPS receiver at RBS site**

At an RBS site equipped with a GPS receiver, one can synchronize RBs using GPS timing data. This solution, which is very accurate, is also used to synchronize radio networks. Notwithstanding, it requires a clear line of sight from the GPS antenna to the satellites in the sky. In many installations, however, this is impossible to achieve, which eliminates GPS as the synchronization solution of choice for such sites.

**RBS synchronization with Abis over IP**

In Ericsson’s solution, the STN provides RBs with the timing they need to fulfill the
RBS synchronization with Abis over IP: time-stamping example.

Figure 4

The supported network may be a switched or routed network that includes xDSL-through-DSLAM access or a satellite hop. The WAN interface of the STN can be Ethernet 10/100/1000BASE or E1/T1. Due to traffic-load-dependent processing and scheduling delays in network nodes, the IP packet transfer delay (IPTD) can accommodate wander components with a periodicity of days. Calibration may continue for up to 15 days on IP networks with large IPTD wander.

The Ericsson Abis over IP solution to RBS synchronization can be employed over IP networks with existing switching and routing equipment in intermediate nodes. The solution can handle the packet delay variation added by these intermediate nodes. All existing intermediate nodes support the message data format used by the timing packets. The highly stable OCXO keeps startup time independent of packet delay variation in the IP network.

In the future, the IEEE 1588 protocol might be implemented in some telecommunications networks. However, this will not improve the performance of synchronization or calibration through existing networks unless every network node is replaced with a node that supports an IEEE 1588 boundary clock or transparent clock. With IEEE 1588 techniques implemented in every node, the clients will experience less packet delay variation, which in turn, means that less stable oscillators may be used in client nodes. One consequence of using a less stable oscillator is that startup time becomes dependent on packet delay variation.

Security

Connecting RBSs over IP networks instead of over TDM-based networks sometimes raises security concerns. Although these concerns are not generally motivated by any technical property of IP, a solution is nevertheless often required. There are two main reasons for this:

- the IP network provides connectivity from RBSs to the BSC, OSS, and time server.
- depending on how it has been configured, a network that is shared with other systems might offer widespread connectivity; and
- operators often consider using public or
semi-public IP networks as a means of reducing their costs. Some operators may also have a corporate strategy that mandates specific security solutions when a generic IP network is used.

**Limiting access and potential intrusion**

Ericsson’s *Abis over IP* solution incorporates a number of measures to improve security (Figure 5). For example, it employs

- access control lists in BSC and RBS IP interfaces;
- optional firewalls in front of sensitive nodes, such as BSC and OSS, or at interconnection points between the Abis and core IP networks; and
- IPsec tunnels from the RBS site to BSC and OSS sites or to a secure IP backbone.

IP is implemented natively in all RBS site transport nodes. IPsec termination at BSC and OSS sites is implemented using specific firewalls, and IPsec tunnels are managed from the OSS.

**O&M security**

Because O&M traffic is particularly sensitive from a security viewpoint, all O&M traffic that runs over IP is realized using secure socket shell (SSH) and secured FTP (SFTP). Likewise, user authentication is mandatory for all O&M connections. The system logs an audit trail of operator activity and periodically uploads it to the OSS.

**Protection of insecure transmission**

If the access IP network is untrusted – that is, if it is shared or public – then IPsec should always be used to prevent wiretapping and traffic manipulation. A typical example would be pico base stations, such as the RBS 2409 (Figure 6), which target low-power frequency licenses for the enterprise market.

**Pico and Femto base stations**

In addition, the new architecture opens up completely new business segments. *Abis over IP* yields cost-effective transport for base stations with low traffic, enabling operators to address Pico and Femto-types of solutions (small base stations that require data rates of up to a few hundred kilobits per second between the RBS and BSC).

The Pico cell solution, for example, is a complete RBS 2000 base station with one TRX. Among other things, operators can use this solution to offer dedicated capacity, coverage and services to small or medium-sized enterprises, which benefit from dedicated GSM telephony. In this scenario, operators could even offer special tariffs when users are in the office. This solution represents a replacement to fixed phones. Previously, the backhaul cost of an E1 prohibited these types of solutions, but with *Abis over IP* and a cheaper DSL type of backhaul (or even the corporate LAN itself), the Pico solution becomes economically feasible.

Femto cell solutions give operators similar opportunities to go after the home market with an offer of inexpensive (or free) calls at home using any standard GSM or WCDMA phone. The Femto runs *Abis over IP* to the BSC/RNC using the home broadband IP connection for backhaul. Special optimizations handle low-cost, low-bandwidth ADSL links. *Abis over IP* thus creates a completely new business opportunity by giving operators an entirely new way of building GSM networks – where end-users introduce new cells into the network.

**Satellites**

Satellites have been used for a number of years to provide connectivity with base station sites in remote locations. Single-channel-per-carrier (SCPC) connections have traditionally served as a leased E1/T1 connection that provides point-to-point connectivity. Transmission for these sites is expensive because the satellite connection requires the full SCPC bandwidth even when there is no traffic from the site.

Today, however, the introduction of *Abis over IP* and advances in satellite modem technology make it possible to reduce transmission expenses for remote sites. Advanced modulation techniques increase the bit rate per hertz, and bandwidth-sharing technology allows sites to "share" satellite bandwidth by means of point-to-multipoint connections and a resources-in-pool concept.

With current satellite bandwidth pric-
Satellite transport is flexible and easy to use, allowing for rapid, small-scale deployments. As demand grows, operators can easily adjust satellite transport as needed. If demand justifies terrestrial transport, one can redeploy satellite equipment and bandwidth, since it is not dependent on location (ordinarily, one satellite can cover an entire continent).

However, to take full advantage of these advances in technology, one must carefully engineer the system end-to-end. With its combined knowledge of radio access, IP backbone and satellite technology, Ericsson is uniquely positioned to deliver the lowest TCO for BTSs connected via satellite.

**Microwave**

Microwave links are used extensively for base station backhaul – at present, more than 60% of all base stations are connected via microwave links. The majority of operators seek to minimize their operating expenses (OPEX) by owning their own transport networks instead of leasing capacity. In operator-owned transport networks, up to 95% of associated base stations are connected via microwave links.

Although traditional microwave links might provide bridged Ethernet capability, this does not automatically imply a reduction in costs in an IP or Ethernet scenario. In a network deployment, on the other hand, the aggregation and statistical multiplexing gains result in more efficient handling of traffic capacity. Therefore substantial gains may also be achieved by moving to Packet Abis over traditional microwave links that support Ethernet over TDM. In addition, new-generation microwave links with native Ethernet transport, QoS support, and adaptive modulation microwave links offer a unique way of providing best-effort traffic transport in combination with guaranteed transport for TDM traffic. This further supports the evolution of the packet-based transport in the radio access network.

Adaptive modulation microwave links enable operators to transport best-effort traffic alongside guaranteed TDM traffic. The idea is to plan the microwave links for a target availability, say 99.999%, when operating at a given modulation, for example, 4QAM. In practice, the links usually operate far above the receiver threshold and only approach the receiver limit during very adverse fading conditions. As a consequence, Ericsson plans to introduce microwave systems that adapt modulation schemes to fading conditions. These systems will deliver different transport bit rates for different atmospheric conditions.

Figure 7 shows availability when a microwave link runs at different modulation rates. A link that uses 4QAM, for example, can deliver 34Mbps with 99.999% availability. When it uses 256QAM, this same link has 99.999% availability and can deliver 196Mbps. This capacity could be employed to provide 34Mbps guaranteed traffic with 99.999% availability and best-effort capacity of approximately 150Mbps, also with 99.999% availability. Links of this kind can provide a competitive, cost-effective alternative for a capacity-growth scenario in which the bulk of traffic is mobile data with best-effort characteristics.

**Future Packet Abis development**

The site-transmission-node function and the Abis over IP feature also constitute the cornerstone of Ericsson's evolving Mobile Softswitch concept, which reaches all the way to the RBS. Given that the majority of calls are local, the ability to keep payload within the RBS and route it directly to the RBS that serves B-subscribers will further reduce op-
erator TCO. Ericsson has thus introduced a new IP payload interface between RBSs and M-MGWs, to enable direct transfer of payload from a mobile subscriber to a local fixed exchange.

RBS local switching and direct transfer of payload are optional features deployed on existing GSM network infrastructure from Ericsson. No additional hardware is required to deploy RBS local switching apart from the *Abis over IP* feature, with its SIU hardware at the RBSs and PGW hardware in the BSC. Instead, one can realize RBS local switching and direct transfer of payload to M-MGWs by means of new functionality in the BSS MAP signaling protocol between the MSC-S and BSC. Ericsson's BSS MAP interface exchanges information between nodes, making it possible to analyze the codec capabilities of involved terminals, and to select the best common denominator. This eliminates the need for intermediate transcoding, effectively removing two transcoding steps, while rendering better voice quality and reducing delay.

The same basic AXE functionality used to transform the MSC into an MSC-S has been applied to the BSC. Likewise, the signaling protocol between the BSC PGW and the STN has been enhanced to facilitate softswitch functionality in the STN.

To transfer payload directly from RBSs to M-MGWs, the GCP protocol has been enhanced and the M-MGW has been complemented to support every codec used in GSM.

With these additions of functionality on top of the packet-switched *Abis over IP* solution, Ericsson has evolved the GSM architecture from its original hierarchical structure to a completely flat architecture. Ericsson’s GSM system is thus poised for the final phase of building GSM coverage for everyone, everywhere. The flat architecture eliminates the problem of tromboning local traffic in remote locations which are served by few RBSs and which cannot carry the cost of a remotely located BSC.

By reducing costs, the new architecture enables operators to profitably build coverage in heretofore “unfeasible” locations. In addition, large areas covered by sites connected via satellite benefit from reduced OPEX. This, in turn, lowers optimal subscriber tariffs and makes service available to an even larger group of users. The flat GSM architecture will also create new business opportunities where there are large volumes of local calls, for example, at corporate campuses.

### Conclusion

Traditional transmission from RBSs to a BSC has not been optimized for efficient transmission of bursty data traffic, nor is it easily adapted to the low-cost transport technologies, such as IP and Ethernet. However, recent developments in GSM transport and switching technologies promise to overcome these issues, making GSM suitable to provide services both to low-revenue users and to users of high-speed data services.

Packet Abis over IP is a collective solution for these developments, including a new protocol for transferring data over the Abis link. From the air interface, the solution sends all traffic in packets over Abis with a minimum of re-packing and re-formating. The solution, which is built on *Abis Optimization* and *Abis over IP* features, can be used over TDM transport networks as well as with IP or Ethernet transport services.

*Abis Optimization* delivers Packet Abis over IP transport networks, saving bandwidth by solely transferring bits that contain informative data. Ericsson has integrated the *Abis Optimization* solution into its BSS. The *Abis over IP* feature enables operators to use IP and Ethernet transport networks to connect RBSs to the BSC and thereby benefit from the lower costs of IP- and Ethernet-based transport services. The solution also opens the door to shared transport with WCDMA and to integrated transport solutions for RBS sites.

To improve security, Ericsson’s *Abis over IP* solution incorporates access control lists in BSC and RBS IP interfaces, optional firewalls in front of sensitive nodes or at interconnection points between the Abis and core IP networks, and IPsec tunnels from the RBS site to BSC and OSS sites or to a secure IP backbone. All O&M traffic that runs over IP is realized using SSH and SFTP.

The new architecture opens up completely new business segments. *Abis over IP* yields cost-effective transport for base stations with low traffic, enabling operators to address Pico and Femto types of solutions.

What is more, the introduction of *Abis over IP* and advances in satellite modem technology makes it possible to reduce transmission expenses for remote sites.

Finally, operators who move to Packet Abis over traditional microwave links that support Ethernet over TDM may enjoy substantial gains in the handling of traffic capacity.

### TERMS AND ABBREVIATION

<table>
<thead>
<tr>
<th>ADSL</th>
<th>Asymmetrical DSL</th>
<th>MSC-S</th>
<th>MSC system</th>
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<tr>
<td>ARPU</td>
<td>Average revenue per user</td>
<td>NTP</td>
<td>Network time protocol</td>
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<td>BSC</td>
<td>Base station controller</td>
<td>O&amp;M</td>
<td>Operation and maintenance</td>
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<td>BSS</td>
<td>Basic station subsystem</td>
<td>OPEX</td>
<td>Operation expenses</td>
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<td>BTS</td>
<td>Base station transceiver</td>
<td>OSS</td>
<td>Operations support system</td>
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<tr>
<td>CS</td>
<td>Circuit switched</td>
<td>OCXO</td>
<td>Oven compensated crystal oscillator</td>
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<tr>
<td>DSL</td>
<td>Digital subscriber line</td>
<td>PDH</td>
<td>Plesiochronous digital hierarchy</td>
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<td>DSLAM</td>
<td>DSL access multiplexer</td>
<td>PGW</td>
<td>Packet gateway</td>
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<td>DTX</td>
<td>Discontinuous transmission</td>
<td>PSTU</td>
<td>Packet-switched termination unit</td>
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<td>E1</td>
<td>2.048Mbps data circuit (Europe)</td>
<td>QAM</td>
<td>Quadrature amplitude multiplexing</td>
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<td>EDGE</td>
<td>Enhanced data for GSM evolution</td>
<td>RAN</td>
<td>Radio access network</td>
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<td>EGPRS</td>
<td>Enhanced GPRS</td>
<td>RBS</td>
<td>Radio base station</td>
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<tr>
<td>FTP</td>
<td>File transfer protocol</td>
<td>SCC</td>
<td>Single carrier channel per carrier</td>
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<tr>
<td>GCP</td>
<td>Generic protocol</td>
<td>SFTP</td>
<td>Secured FTP</td>
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<tr>
<td>GPRS</td>
<td>General packet radio service</td>
<td>SDH</td>
<td>Synchronous digital hierarchy</td>
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<tr>
<td>GPS</td>
<td>Global positioning system</td>
<td>SIU</td>
<td>Site integration unit</td>
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<tr>
<td>GRE</td>
<td>Generic routing encapsulation</td>
<td>SONET</td>
<td>Synchronous optical network</td>
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<tr>
<td>GSM</td>
<td>Global system for mobile communications</td>
<td>SSH</td>
<td>Secure socket shell</td>
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<tr>
<td>IP</td>
<td>Internet protocol</td>
<td>STM</td>
<td>Synchronous transfer mode</td>
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<td>IPsec</td>
<td>Secure IP</td>
<td>Site</td>
<td>Site transport node</td>
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<td>IPTD</td>
<td>IP packet transfer delay</td>
<td>T1</td>
<td>1.544Mbps data circuit</td>
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<tr>
<td>LAN</td>
<td>Local area network</td>
<td>TCH</td>
<td>Traffic channel on the air interface</td>
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<td>MAP</td>
<td>Mobile application part</td>
<td>TCO</td>
<td>Total cost of ownership</td>
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<td>MGW</td>
<td>Media gateway</td>
<td>TDM</td>
<td>Time-division multiplexing</td>
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<td>MLPP</td>
<td>Multilink point-to-point protocol</td>
<td>TRX</td>
<td>Transceiver</td>
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<td>M-MGW</td>
<td>Mobile MGW</td>
<td>VoIP</td>
<td>Voice over IP</td>
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<td>MPLS</td>
<td>Multiprotocol label switching</td>
<td>WAN</td>
<td>Wide area network</td>
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<tr>
<td>MSC</td>
<td>Mobile switching/service center</td>
<td>WCDMA</td>
<td>Wideband code-division</td>
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