CHAPTER 8

Network

8.1 General Discussion

A one-sentence description of the 3GPP concept might be: “a CDMA packet-based air interface combined with a GSM + GPRS core network.” ITU’s 3G concept, known as IMT-2000, includes several other accepted technologies for 3G systems. However, the referenced WCDMA + GSM combination will be the most widely used. The simple reason for this is the fact that among the second-generation mobile cellular networks, GSM is by far the most widely used technology. All of the significant 3G proposals for IMT-2000 are those that successfully protect the investments in their 2G legacy networks in a 3G world. The 3GPP work strives to protect the GSM investments and bring the markets into 3G. The present-day operators will not want to invest in new networks if they can “recycle” their existing GSM networks. Most big network manufacturers and operators are actively supporting this approach. So for these operators this 3G solution is a good deal, because they can continue to use their upgraded GSM networks. In many cases the radio access network can be updated to conform to the 3G requirements. The mobile phone users however are not so lucky, as they will need new phones that are capable of accessing WCDMA base stations. Most probably, these phones will have to be dual-system GSM + WCDMA phones at first, since the UTRAN radio access network coverage will be quite limited at service launch. The UTRAN may only provide coverage in urban hot-spots in the beginning, as the old GSM networks will be used to provide wide-area service.

The IMT-2000 network is divided into two logical concepts, the core network (CN) and the generic radio access network (GRAN). The noble idea behind this arrangement is that the GRAN will be capable of connecting, perhaps simultaneously, to several different core networks, such as GSM, B-ISDN + IN, or a packet data network. The

GRAN could be implemented, for example, as a GSM BSS, DECT, LAN, CATV, or Hiperlan2, network. 3GPP has also specified a new dedicated UMTS radio access network (RAN) called the UTRAN (UMTS Terrestrial RAN). An important requirement for the GRAN implementations is that they conform to the Iu interface specifications. Note however that the 3GPP Release 99 specifications only contain provisions for the GSM-MAP (including GPRS) and the ANSI-41 core networks.

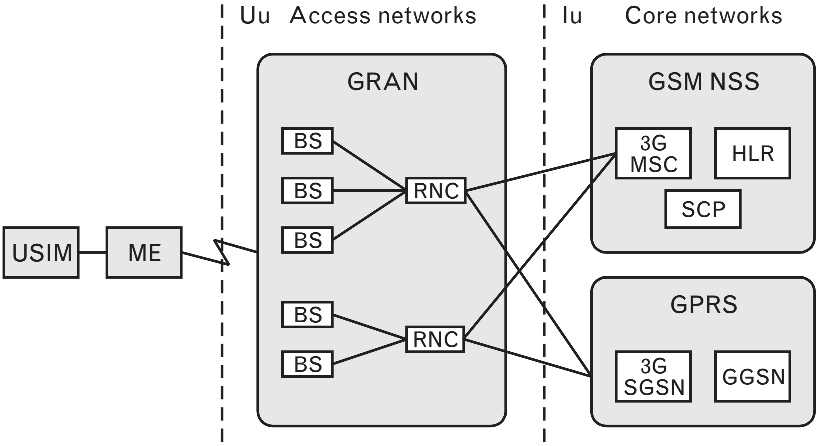
In GSM terms, the GRAN contains the base station subsystem; that is, the BTS and the BSC. In the 3GPP specifications, the generic GRAN concept is translated into a concrete UTRAN network in which the base transceiver station (BTS) has the curious name Node B. The new name for the base station controller (BSC) is the radio network controller (RNC).

Between the GRAN and the core network we find the Iu interface, and between the GRAN and the UE we see the Uu interface (radio interface). See Figure 8.1.

8.2 Evolution from GSM

It must be noted that a GSM phase 2+ network provides a smooth transition path to UMTS, especially if the operator also operates a GPRS network. GSM networks have been updated little by little to include more and more features. Table 8.1 (from [31]) shows how

Figure 8.1 *UMTS architecture.*



well the future GSM 2.5G network will comply with the UMTS requirements.

As we can see in Table 8.1, a GSM network with all the add-ons very closely mimics a UMTS network. The only difference is the more flexible and capable UMTS air interface, which can handle different bearer types at the same time. Real-time services are confined to dedicated connections whereas non-real-time low bandwidth services can quite easily use shared communication channels, which can more easily be changed dynamically.

UMTS can also achieve higher bit rates, but it must be noted that the differences between UMTS and 2.5 GSM are not so large from the user point of view. A GSM with all the 2.5G upgrades could achieve close to 200 Kbps user data rates. In theory (and in the marketing talk) GSM could approach 384 Kbps rates. If a UTRAN network wants to exceed this speed, it has to use very low spreading factors, and allocate the resources of a base station mostly to one user. When a GSM base station offers close to 200 Kbps speeds to one user, it only uses one of its frequency carriers; there are probably several other carriers still available for other users. But a typical WCDMA base station has only one downlink frequency carrier, and if one user is provided with a downlink connection of over 2 Mbps, then other users are left with nothing. In

TABLE 8.1 GSM COMPLIANCE FOR THE UMTS TARGETS

UMTS TARGET	GSM COMPLIANCE
Small affordable hand portables	Yes
Deep penetration (> 50%)	Yes, already in some markets
Anywhere, anytime (indoor, office)	Yes (picocells, GSM office)
Anywhere, satellite mobile interworking	Yes
Hot Spot capacity	Yes (cell hierarchies)
Wireline voice quality	Yes (EFR codec)
Global roaming	Yes (SIM, MAP)
IN services	Yes (CAMEL)
Multimedia, entertainment, nonvoice	Yes (TCP/IP transparency, GPRS, HSCSD)
Flexibility to mix different bearer types (non-real-time and real time)	No
High bit rate services (> 200 kbit/s)	No

practice the situation is not so bad, since high-speed traffic is typically bursty and not continuous, and thus several users can have high data rates momentarily. There are also techniques to enhance the UTRAN's downlink capacity further, like sectorization, smart antennas, and additional scrambling codes.

We can see that a GSM + GPRS combination provides a very good foundation for the UMTS core network building process. The biggest operator investment will clearly be building out the radio access network. We are excluding the operator license fees here, as they are not technology related to the network's implementation. Some of the latest GSM base stations are, however, said to be upgradeable to UTRAN standards.

Note that the easy accommodation of GSM for the UMTS requirements may also be a problem for new UMTS operators, since the existing GSM (non-UMTS) operators can provide almost the same services without the extra UMTS investments. The competition will be hard for the new UTMS operators in the early phases, and it is especially hard for the new UMTS operators, which do not have an existing 2G network. It is very expensive for them to build out wide area coverage 3G networks, while they don't have any income from existing networks. Furthermore, in many countries the operating licenses are very expensive. The combined cost burden from the licensing fees, interest and network construction can push a new green-field operator into a very unfavorable position. Telecommunication authorities may have to do some creative thinking to find ways to help these companies. One way to ease the situation would be to force the current 2G network operators to lease their networks to new 3G operators, so that they can provide wider coverage for their customers from the beginning. There are already successful examples of this concept in the GSM world. New GSM-1800 operators have been able to provide wider coverage by leasing GSM-900 capacity from existing operators in some countries. Note that these old operators are competitors for the new networks, so the telecommunication authority must be very careful in their decisions so that free competition is not obstructed more than absolutely necessary.

8.3 UMTS Network Structure

Figure 8.2 depicts the UMTS architecture at the very highest level. This chapter concentrates on both the core network (CN) and the UTRAN. Section 8.4 discusses the CN, and section 8.5 handles

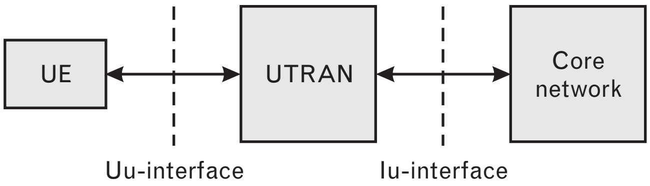


FIGURE 8.2
High-level UMTS architecture.

the UTRAN. The interfaces between the UE and the UTRAN (Uu interface) and between the UTRAN and the CN (Iu) are open multivendor interfaces. Note that most of the first seven chapters of this book are dedicated to the Uu interface, with its WCDMA technology.

The next figure, Figure 8.3, gives a much more detailed description of the UMTS architecture. The reader can see that the core network portion is the same as in the old GSM + GPRS core network combination. The same core network entities may serve both the UTRAN and GSM radio access networks. GSM's radio access network entities (the

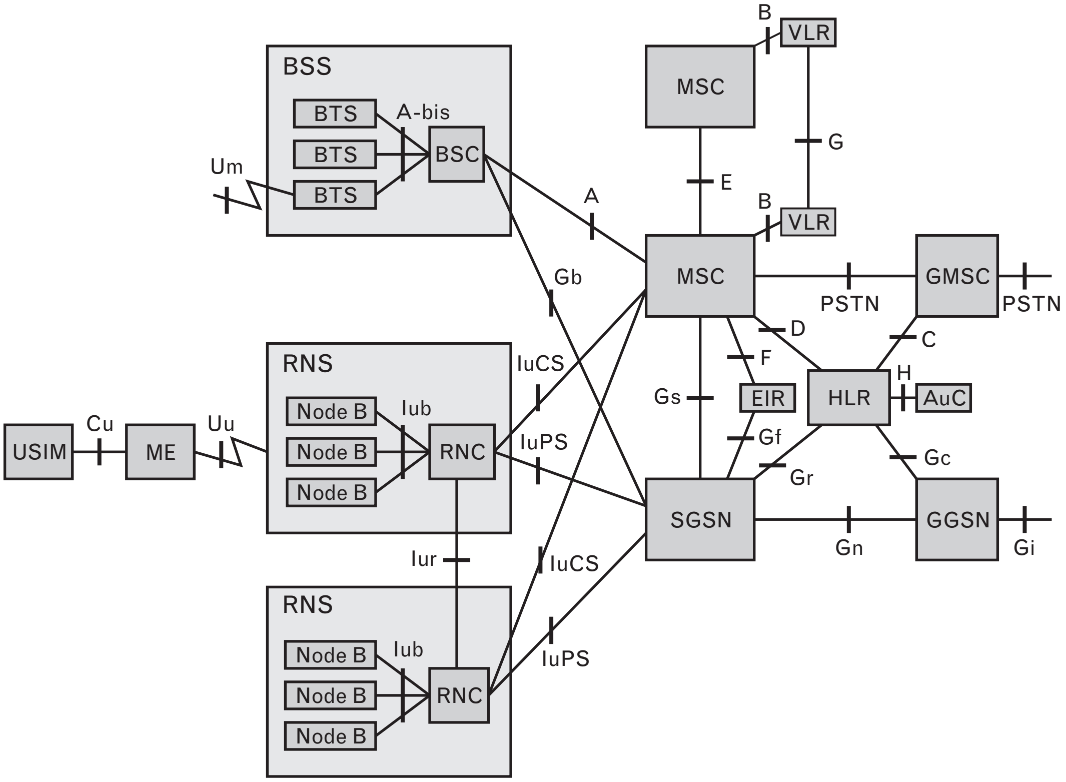


FIGURE 8.3 *UMTS network elements and interfaces.*

BSS) are included in the drawing to clarify the relationship of these two technologies. They are likely to linger in the networks to support traditional circuit-switched speech services.

The entities in this figure are briefly described in the following paragraphs. Since the core network entities are the same as in GSM/GPRS networks, these are not described in every detail, as there is already plenty of literature available for these networks.

Note that this list of network elements is not comprehensive. New services will require new network elements. For example location services (LCS) need various mobile location centers. There are also group call registers, gateway location registers, and so on. For a full and up-to-date description of all the core network elements and interfaces, please refer to [5].

8.4 Core Network

8.4.1 Mobile Switching Center

The mobile switching center (MSC) is the centerpiece of the circuit-switched core network. The same MSC can be used to serve both the GSM-BSS and the UTRAN connections. This kind of MSC must be upgraded somewhat to meet the 3G requirements, but the same MSC can be used to serve the GSM networks. In addition to the radio access networks, it has interfaces to the fixed PSTN network, other MSCs, the packet switched network (SGSN), and various core network registers (HLR, EIR, AuC). Physically the VLR is implemented in connection with the MSC, so the interface between them (the B interface) exists only logically.

Several BSSs can be connected to an MSC. The number of MSCs also varies; a small operator may only have one MSC, but once the number of subscribers increases, several MSCs may be needed.

The functions of an MSC include [1]:

- Paging;
- Coordination of call setup from all MSs in the MSC's jurisdiction;
- Dynamic allocation of resources;
- Location registration;

- Interworking functions (IWFs) with other type of networks;
- Handover management (especially the complex inter-MSC handovers);
- Billing of subscribers (not the actual billing, but collecting the data for the billing center);
- Encryption parameter management;
- Signaling exchange between different interfaces;
- Frequency allocation management in the whole MSC area;
- Echo canceler operation and control.

The MSC terminates the MM and CM protocols of the air interface protocol stack, so the MSC has to manage these protocols, or delegate some responsibilities to other core network elements.

8.4.2 Visitor Location Register

The visitor location register (VLR) contains information about the mobile stations roaming in this MSC area. It is also possible that one VLR handles the visitor register of several MSC areas. Note that a VLR contains information from all active subscribers in its area, even from those to whom this network is their home network. The VLR contains pretty much the same information as the HLR, the difference being that the information in the VLR is there temporarily, while the HLR is a site for permanent information storage. When a user makes a subscription, the subscriber's data is added to his home HLR. From there it is copied to the VLR the user is currently registered with. When a user registers with another network, the subscriber data is removed from the old VLR and copied to the new VLR. There are, however, some network optimization schemes, which may change this principle in the future. See the super-charger and turbo-charger concepts in Sections 12.3 and 12.4.

A VLR subscriber data entry contains the following information:

- International mobile subscriber identity (IMSI);
- Mobile station international ISDN number (MSISDN);
- Mobile station roaming number (MSRN);
- Temporary mobile station identity (TMSI), if applicable;

- Local mobile station identity (LMSI), if used;
- Location area where the mobile station has been registered;
- Identity of the SGSN where the MS has been registered, if applicable;
- Last known location and the initial location of the MS.

In addition, if LCS is supported:

- An indication of whether the location measurement unit (LMU) was successfully registered in an associated serving mobile location center (SMLC);
- The SMLC address.

The VLR may also contain supplementary service parameters. The procedures the VLR has to perform include:

- Authentication procedures with the HLR and the AuC;
- Cipher key management and retrieval from the home HLR/AuC;
- Allocation of new TMSI numbers;
- Tracking of the state of all MSs in its area;
- Paging procedure support (retrieval of the TMSI and the current location area).

The organization of the subscriber data is described in [2].

8.4.3 Home Location Register

The home location register (HLR) contains the permanent subscriber data register. Each subscriber information profile is stored in only one HLR. The HLR can be implemented in the same equipment as the MSC/VLR, but the usual arrangement is to have the MSC/VLR as one unit, and the HLR/AuC/EIR combination as another unit. One PLMN can have several HLRs.

The subscriber information is entered into the HLR when the user makes a subscription. There are two kinds of information in an HLR register entry, permanent and temporary. The permanent data never change, unless the subscription parameters are changed. An example of this is the user who adds some supplementary services to his/her subscription. The temporary data contain things like the current (VLR) address and ciphering information, which can change quite often, even from call to call. Temporary data are also sometimes conditional; that is, it is not always there.

The permanent data in the HLR include:

- International mobile subscriber number (IMSI), which identifies the subscriber (or actually his/her SIM card) unambiguously;
- MSISDN (the directory number of the MS; e.g., +44-1234-654321);
- MS category information;
- Possible roaming restrictions;
- Closed user group (CUG) membership data;
- Supplementary services parameters;
- Authentication key;
- Network access mode (NAM), determining whether the user can access the GPRS networks, non-GPRS networks, or both.

In addition, if GPRS is supported:

- PDP addresses.

If LCS is supported:

- Location measurement unit (LMU) indicator.

The temporary data include:

- Local mobile station identity (LMSI); Triplet vector; that is, three authentication and ciphering parameters: (1) random number (RAND), (2) signed response (SRES), and (3) ciphering key (Kc);
- Quintuplet vector; that is, five authentication and ciphering parameters: (1) random challenge (RAND), (2) expected response

(XRES), (3) cipher key (CK), (4) integrity key (IK), and (5) authentication token (AUTN);

- MSC number;
- VLR number (the identity of the currently registered VLR).

In addition, if GPRS is supported:

- SGSN number (the SS7 address of the SGSN).

And if LCS is supported:

- LCS privacy exception list;
- List of gateway mobile location centers (GMLCs) in the HPLMN.

Note that these lists are not exhaustive, as the subscriber data registers can contain a lot of information (dozens of different entries). The subscriber data organization in the core network is specified in [2]. The tables in the end of that specification give a good picture of what information is stored and where.

The HLR also forwards the charging information to the billing center.

8.4.4 Equipment Identity Register

The equipment identity register (EIR) stores the international mobile equipment identities (IMEIs) used in the system. An EIR may contain three separate lists:

- *White list*: The IMEIs of the equipment known to be in good order;
- *Black list:* The IMEIs of any equipment reported to be stolen;
- *Gray list:* The IMEIs of the equipment known to contain problems (such as faulty software), but which are not fatal enough to justify barring them.

At a minimum an EIR must contain a white list. It is unfortunate that the black list and the checks against it are not mandatory, as stolen mobile phones can now be used in some networks that have a weaker security policy.

Typically a PLMN has only one EIR, which then interconnects to all HLRs in the network. Note that EIR handles IMEI values, not IMSIs or any other identities. The IMEI is (or should be) a unique identity of a mobile handset and is assigned to it when manufactured.

8.4.5 Authentication Center

The authentication center (AuC) is associated with an HLR. The AuC stores the subscriber authentication key, Ki, and the corresponding IMSI. These are permanent data entered at subscription time. The Ki key is used to generate an authentication parameter triplet (Kc, SRES, RAND) during the authentication procedure. Parameter Kc is also used in encryption algorithm.

An AuC physically always exists with an HLR. The MAP-interface between them (the H interface) has not been standardized.

8.4.6 Gateway MSC

The Gateway MSC (GMSC) is an MSC that is located between the PSTN and the other MSCs in the network. Its function is to route the incoming calls to the appropriate MSCs. Note that the PSTNs outside the PLMN cannot access its HLRs, and thus they cannot route the calls to the right MSC by themselves.

In practice it is also possible that all MSCs are also GMSCs in a PLMN.

8.4.7 Serving GPRS Support Node

The serving GPRS support node (SGSN) is the central element in the packet-switched network. It contains two types of information:

- Subscription information;
- IMSI;
- Temporary identities;
- PDP addresses;
- Location information;

- The cell or the routing area where the MS is registered;
- VLR number;
- GGSN address of each GGSN for which an active PDP context exists.

The SGSN connects to the UTRAN via the IuPS interface and to the BSS via the Gb interface. It also has interfaces to many other network elements as seen in Figure 8.3.

8.4.8 Gateway GPRS Support Node

The gateway GPRS support node (GGSN) corresponds to the GMSC in the circuit-switched network. But whereas the GMSC only routes the incoming traffic, the GGSN must also route the outgoing traffic. It has to maintain the following data:

- Subscription information;
- IMSI;
- PDP addresses;
- Location information;
- The SGSN address of the SGSN where the MS is registered.

The GGSN receives this information from the HLR and from the SGSN.

8.5 UMTS Radio Access Network

The UMTS Radio Access Network (UTRAN) is the new radio access network designed especially for UMTS. Its boundaries are the Iu interface to the core network and the Uu interface (radio interface) to user equipment (UE).

The UTRAN is just one realization of the Generic Radio Access Network (GRAN) concept. The other possible implementations in the future may include, for example, the Broadband Radio Access Network (BRAN) and the UMTS Satellite Radio Access Network (USRAN) access networks.

The UTRAN consists of radio network controllers (RNCs) and Node Bs (base stations). Together these entities form a radio network subsystem (RNS). See Figure 8.4.

The internal interfaces of the UTRAN include the Iub and Iur. The Iub connects a Node B to the RNC and the Iur is a link between two RNCs.

The Iub is intended to be an open interface, but it is situated in so delicate a position in the network infrastructure that it is also possible that it will, in practice, become a manufacturer proprietary interface. The corresponding interface in GSM (A-bis) is like that; one has to use compatible equipment from the same manufacturer in both sides of the Abis interface. The Iub interface has to manage difficult issues like power control and thus the manufacturers are tempted to use their own proprietary solutions here.

8.5.1 Radio Network Controller

The radio network controller (RNC) controls one or more Node Bs. It may be connected via the Iu interface to an MSC (IuCS) or to an SGSN (IuPS). The interface between RNCs (Iur) is a logical interface, and a direct physical connection doesn't necessarily exist. An RNC is comparable to a base station controller (BSC) in GSM networks.

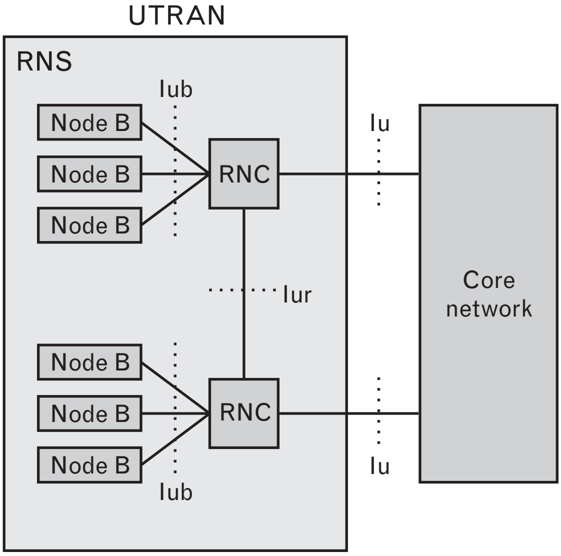


Figure 8.4
UTRAN components and interfaces.

Functions that are performed by the RNC include:

- Iub transport resources management;
- Control of Node B logical O&M resources;
- System information management and scheduling of system information;
- Traffic management of common channels;
- Macro diversity combining/splitting of data streams transferred over several Node Bs;
- Modifications to active sets; that is, soft handover;
- Allocation of downlink channelization codes;
- Uplink outer-loop power control;
- Downlink power control;
- Admission control;
- Reporting management;
- Traffic management of shared channels.

8.5.2 Node B

Node B is the UMTS equivalent of a base station transceiver. It may support one or more cells, although in general the specifications only talk about one cell per Node B. The Node B term is generally used as a logical concept. When physical entities are referred to, then the Base Station term is often used instead.

Functions that are performed by a Node B include:

- Node B logical O&M implementation;
- Mapping of Node B logical resources onto hardware resources;
- Transmitting of system information messages according to scheduling parameters given by the RNC;
- Macrodiversity combining/splitting of data streams internal to Node B;
- Uplink inner-loop power control (in FDD mode);
- Reporting of uplink interference measurements and downlink power information.

In addition, because Node B also contains the air interface physical layer, it has to perform the following functions related to it (these are further discussed in Chapter 3):

- Macrodiversity distribution/combining and soft handover execution;
- Error detection on transport channels and indication to higher layers;
- FEC encoding/decoding of transport channels;
- Multiplexing of transport channels and demultiplexing of CCTrCHs;
- Rate matching;
- Mapping of CCTrCHs on physical channels;
- Power weighting and combining of physical channels;
- Modulation and spreading/demodulation and despreading of physical channels;
- Frequency and time synchronization;
- Radio measurements and indication to higher layers;
- Inner-loop power control;
- RF processing.

Network manufacturers are also offering solutions where the same physical base station equipment will offer both the GSM and the WCDMA transmitter/receiver capability (i.e., they are combined GSM-BTS and WCDMA-Node Bs).

8.6 GSM Radio Access Network

The GSM radio access network is also known as the base station subsystem (BSS). It consists of one base station controller (BSC) and one or more base transceiver stations (BTS), as in Figure 8.5. The BSC controls the functionality of a BTS over the A-bis interface. The A-bis interface is not a multivendor interface, but it contains solutions, which are proprietary to each manufacturer. The functional

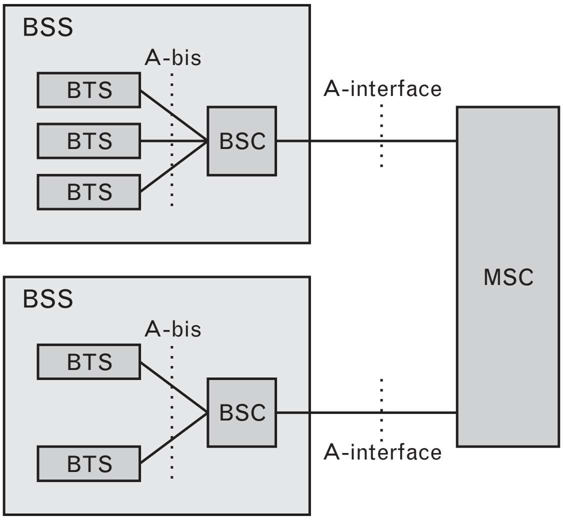


FIGURE 8.5
BSS subsystem.

split between the BSC and the BTS is such that the BTS should contain only the transmission equipment and related functions, and the managing equipment and everything else should be in the BSC. Generally it can be said that the intelligence in this system lies in the BSC. The BTS is purposely left quite dumb, as it is then cheaper to build. Note that the number of BTSs in a mobile network is much greater than the number of BSCs, so designing a "super-BSC" and a simple BTS makes sense. A good presentation of base station subsystem architecture can be found in[1].

8.6.1 Base Station Controller

A BSC controls a group of BTSs connected to it via the A-bis interface. The number of BTSs under its control depends on the network configuration. The BSC functions include:

- Radio resource management for BTSs;
- Intercell handovers (for inter-BSC handovers, help is needed from the MSC);
- Frequency management (allocation of frequencies to BTSs);
- Management of frequency-hopping sequences;

- Time-delay measurements of uplink signals with respect to the BTS clock;
- Implementation of the operation and maintenance (O&M) interface;
- Traffic concentration to reduce the number of required lines to BTSs and an MSC;
- Power management.

8.6.2 Base Transceiver Station

The BTS consists of one or more transceivers (TRXs). Each TRX can support one carrier; that is, eight time slots. Eight time slots on a radio carrier constitute eight physical channels. Note that it is not possible to use all time slots for traffic channels, as common control channels do require part of the capacity. Typically a BTS serves one cell. There are also configurations in which several sectored cells are transmitted from the same BTS site. This can be regarded as one BTS with several sectored cells, or several BTSs each with a sectored cell. The radius of BTS cells can vary a great deal. The smallest BTS cells are indoor cells with a radius of just a few meters. At the other extreme, the maximum theoretical radius of a basic-GSM cell is just over 30 kms. In practice this can be used only in open rural areas. There are also modified BTSs with a radius of 70 km. These have, however, a rather poor spectral efficiency and thus they are only used in special circumstances when a large coverage is required but the expected traffic density is very low. Ensuring that the layout of BTSs provides wide enough coverage and simultaneously enough capacity in traffic hot spots is a major task for network operators. Network planning is discussed further in Chapter 9, although the discussion there is mostly about WCDMA networks.

The GSM specifications define that the transcoder/rate adapter unit (TRAU) is also part of the BTS. However, it is common practice that this unit is located at the MSC. The function of the transcoder is to convert the digitized speech (full rate [FR] or enhanced full rate [EFR] coded ~ 13 Kbps) from the GSM air interface into 64 Kbps PCM speech used in telephone networks and vice versa. It makes sense to locate this unit as close as possible in the middle of the network, because this preserves the required transport capacity. One can transfer four times more GSM FR coded channels than PCM coded channels. A 13-Kbps channel is padded with extra bits to make it a 16-Kbps channel, and four of these can be carried over a single 64-Kbps channel. Therefore the most common location for TRAUs is at the MSC, although logically it is still part of the BSS.

The BTS functions include:

- Scheduling of broadcast and common control channels;
- Detection of random and handover access bursts sent by the mobile stations;
- Timing advance calculations;
- Uplink measurements;
- Channel coding (error protection) and encryption/decryption;
- LAPDm protocol (layer 2);
- Frequency hopping;
- Transcoding and rate adaptation (although this is usually handled by an MSC).

8.6.3 Small Base Transceiver Stations

The latest trend in GSM base station systems is the development of very small base stations. Traditionally, GSM has not been a very suitable system for low-tier environments, such as homes and indoor office systems. The GSM infrastructure has been relatively complex and expensive compared with simpler systems designed for the wireless office and similar applications, and it has, therefore, been out of reach for domestic use. The traffic density can be quite high in offices, and GSM has not been able to easily provide coverage for traffic hot spots. Also, network planning in GSM is a complex operation. One cannot just nail a GSM home base station to one's living room wall and expect that all of one's neighbors with similar systems (possibly using the same frequency) would remain friendly. However, these problems must be solved, as in the future the GSM network needs to expand to just these kinds of areas. This issue is discussed here because even though the low-tier GSM BSS is not a 3G issue as such, it will be increasingly used in the future and it will be a competitor of 3G networks. Many WCDMA operators will have GSM licenses, and they will have a choice of two technologies when planning indoor networks. Actually there are three alternatives, if we include both the FDD and TDD modes of WCDMA. Silventoinen [9] presents two different indoor scenarios, analyzing their problems and proposing possible solutions.

The home base station (HBS) is aimed at residential use. Currently the customer looking for cheap call rates at home has to use either a fixed-line telephone or some cordless technology, like DECT or CT2. GSM mobile phone calls are more expensive, although the general trend is toward lower tariffs. Using one's GSM phone at home is, nevertheless, an attractive concept, as the handsets take on more and more PDA features. An HBS must be affordable, therefore its capabilities are less than those of a "real" base station. There are many technical problems with the HBS concept. The two major ones are frequency allocation and the HBS synchronization. The problem with frequency allocation results from the fact that HBSs are probably set up without any input from the local operators, and there cannot, therefore, be any centralized frequency planning. Since the HBS is an indoor system, the interference caused to the normal GSM network will probably be small. But the stronger outdoor GSM network could severely interfere with the functionality of an HBS. Automatic search receivers could solve the interference problem, but they would add far too much cost to the HBS.

HBS synchronization is a problem because an HBS is most likely connected to a PSTN, which cannot provide a suitable time or frequency reference. This may cause a drift in both the time and frequency domains, which can increase system interference and reduce spectral efficiency. There are solutions to all of these problems, but the low-cost character of the HBS restricts the viable methods, so that the price tag of this system remains low.

The two main HBS scenarios presented are the cordless approach and the base station approach. In the cordless approach, the HBS serves only as an access point to the PSTN. Therefore, any GSM-specific services cannot be used when the mobile is connected to an HBS. This approach is easier to implement, but it is not an attractive technology choice for the GSM operators, as they cannot get any revenues from the calls made via cordless HBSs. ETSI promotes this approach under the name of the cordless telephone system (CTS); see [10] and [11].

In the base station approach, the HBS is connected to the normal GSM network via the PSTN. This would require specifying a new protocol for the HBS-GSM PSTN interface. Specification work is always slow, and thus this approach may never be implemented. However, the

GSM operators would certainly like this alternative much more, as the calls would go via their infrastructure and bills could be sent out for the service.

Office base stations, although they are also indoor systems, differ from home base stations in many ways. Whereas with the HBS the traffic density most probably will not be a problem, office base stations are usually built just to tackle the problem of traffic hot spots. Because of the high number of users, the cost of the base station equipment is not an important factor, as it is with HBSs. Silventoinen [9] presents three possible alternatives for office systems: single cell, multicell, and a hybrid system called the in-building base station system (IBS).

In a single-cell system there is only one cell for the entire office. This is a technically simple system to implement. No network planning is needed, since there is only one cell. Thus there are no intraoffice handovers. The drawback is that this system has a poor spectral efficiency. The capacity can be increased only by allocating more carriers to the system. Small GSM operators may not have enough bandwidth available, especially if the office is large and the traffic density high.

In multicell systems, the office is divided into several small cells. The capacity can be increased more easily in this kind of system just by increasing the number of cells. But this is technically a rather complex system, as it requires tedious network planning. Intraoffice handovers do happen frequently, and in relatively modest systems there cannot be any frequency reuse if the number of cells is lower than the minimum reuse factor. Setting up a multicell system is certainly a much costlier solution than implementing a single-cell system.

The hybrid IBS office system tries to combine the good properties of the previous two approaches. It contains a single logical cell, which is then divided into several radio subcells. These subcells can use much simpler transmitters than “real” BTSs. The low-cost transmitters are called RF-heads. TRXs are kept in a centralized HUB that corresponds to the BTS. The problem with this approach is that the RR protocol task in the HUB needs some modifications to cope with it. The old definition of the channel (i.e., frequency/timeslot pair), is no longer sufficient in the IBS, because the channel now has a third dimension: place. The same frequency/time slot can be reused in some other RF-head. Thus, although the IBS approach is technically better than the two other approaches, it requires changes to the current specification and therefore it is not readily available. Single-cell and multicell systems can be deployed immediately.

8.7 Interfaces

The interfaces in the UMTS system follow the GSM/GPRS naming convention, where applicable. The UTRAN contains some new interfaces, and thus some new names.

From the specifications point of view, there are three kinds of interfaces in the UMTS/GSM network. The first category contains those interfaces that are truly open. This means that they are specified, and the specification is such that the equipment on different ends of the interface can be acquired from different manufacturers. In an old GSM network, only the A-interface and the air interface are truly open interfaces.

The second category includes those interfaces that are specified at some level, but the interface is still proprietary. The equipment for such interfaces must come from the same manufacturer, as the implementation is specific to a manufacturer. The Abis-interface is a good example of such an interface. It is rather well specified as a whole, but some issues are left open, and thus it is not an open interface. Sometimes an interface exists only logically if two devices are physically only one entity. Quite often the MSC and the VLR are combined, and thus the B-interface doesn't physically exist.

The third category contains those interfaces for which there is no specification at all. The interface has only a name, and possibly a description of the tasks it should be able to handle. The H- and I-interfaces in the GSM core network belong to this category. Obviously these interfaces are not open. They are either proprietary or they are not used at all in some cases.

The following paragraphs contain a short description of these interfaces. For a detailed description see [3] and [4] for the GSM interfaces, and [5] and [6] for the UMTS interfaces.

8.7.1 A-Interface

The A-interface exists between the MSC and the BSC, which is logically the BSS. This interface is an open multivendor interface, which should mean that an operator can buy the MSC and the BSS equipment from different manufacturers and connect them together over the A-interface. This interface is specified in the 08-series GSM specifications. Though the A-interface is a pure GSM interface, and not part of the UMTS concept, it can connect a BSS subsystem to a 3G-MSC, which makes it eligible for examination in this section.

The protocol stack for the A-interface is depicted in Figure 8.6. This diagram shows the protocol stacks for the whole BSS subsystem as well as A-interface as discussed here. The other protocols are pure GSM protocols, which can be studied in [1], [3], and [7].

8.7.2 Gb-Interface

The Gb-interface is a non-UMTS interface, which will often be present in the UMTS core network. The Gb-interface connects the packet-switched core network to the GSM network. It is used when the GSM mobile station uses GPRS services. GPRS-capable GSM phones of the future will be able to use at least some of the UMTS packet-based services, especially once enhanced GPRS (EGPRS) is launched. EGPRS can expand the user data speeds in the GSM air interface up to rates as high as 200 Kbps. This will certainly give EGPRS phones the ability to use many of the 3G services and applications if the operator so allows. Note that the combined RLC/MAC protocol used in the radio interface in GPRS is not the same protocol as the separate RLC and MAC protocols used in the UTRAN air interface. See Figure 8.7.

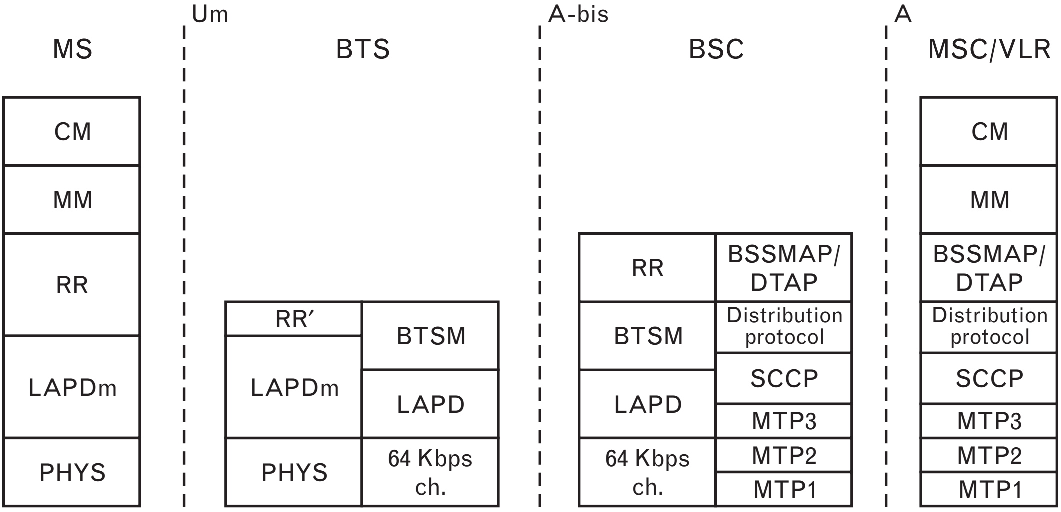


FIGURE 8.6 *GSM BSS protocols.*

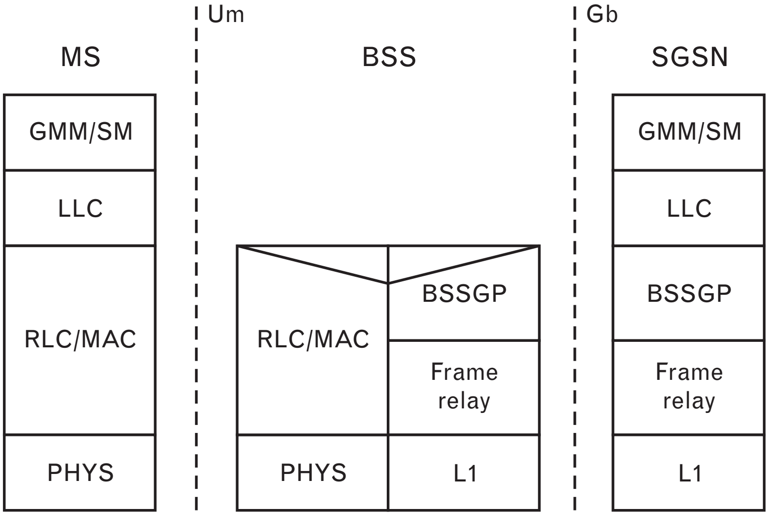


FIGURE 8.7 *GPRS BSS signaling protocols.*

8.7.3 Iu-Interface

This interface connects the core network and the UMTS Radio Access Network (URAN). A truly open, multivendor interface, it is the most important and central interface for the 3GPP concept. The Iu can have two different physical instances, Iu-CS and Iu-PS, and there will probably be more in the future. The Iu-CS connects the radio access network to a circuit-switched core network; that is, to an MSC. The Iu-PS connects the access network to a packet-switched core network, which in practice means a connection to an SGSN.

The URAN can have several kinds of physical implementations. The first to be implemented is the UMTS Terrestrial Radio Access Network (UTRAN), which uses the WCDMA air interface technology. Thus, the URAN is a generic concept and the UTRAN will be the first concrete implementation of it. Specification work is also under way for the Broadband Radio Access Network (BRAN), which connects a HIPERLAN2 radio access network to a core network. The URAN concept and BRAN are depicted in Figure 8.8. AP stands for "access point," and APC for "access point controller."

BRAN is being specified by ETSI, and it can support user data rates around 30 Mbps. The maximum physical rate is 54 Mbps. HIPERLAN2 uses unlicensed radio spectrum in the 5-GHz radio band. It can provide a coverage range of 30–50m indoors and up to 150–200m outdoors. A typical application for HIPERLAN2 includes laptops with wireless modems in office and campus environments.

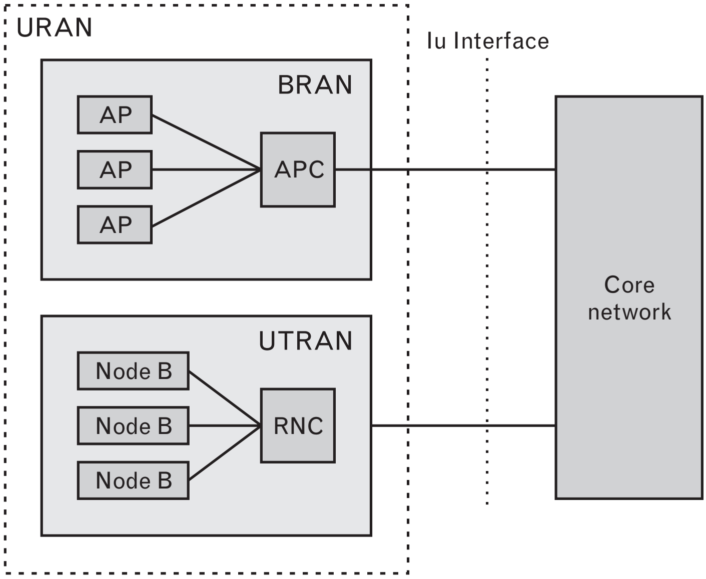


Figure 8.8 *BRAN and UMTS interworking.*

However, the maximum data rates are so high that they provide lots of possibilities for totally new kinds of application. HIPERLAN2 is well explained in [12].

It will be possible to execute handovers between UTRAN and BRAN, provided that the user terminal is a dual-system UMTS-HIPERLAN terminal.

The UMTS Satellite Radio Access Network (USRAN) connects a satellite network to the core network. This access network had not been specified as of 2001, and it will not be implemented in the near future. Several different satellite access networks have been proposed to the ITU for a 3G system, but only time will show which of those will survive to develop into concrete systems. Satellite cellular business during the last few years has been especially difficult, and we have seen some remarkable failures. Some uncertainty remains as to whether there will be enough customers for a commercially viable satellite cellular system.

The protocol model in the Iu-interface is divided into two horizontal layers, the radio network layer and the transport network layer. This is depicted in Figure 8.9. The split is made to separate the transport technology (in the transport network layer) from the UTRAN-related issues (in the radio network layer).

This picture may look a bit confusing at first. A protocol stack diagram usually has two planes, control and user. The control plane

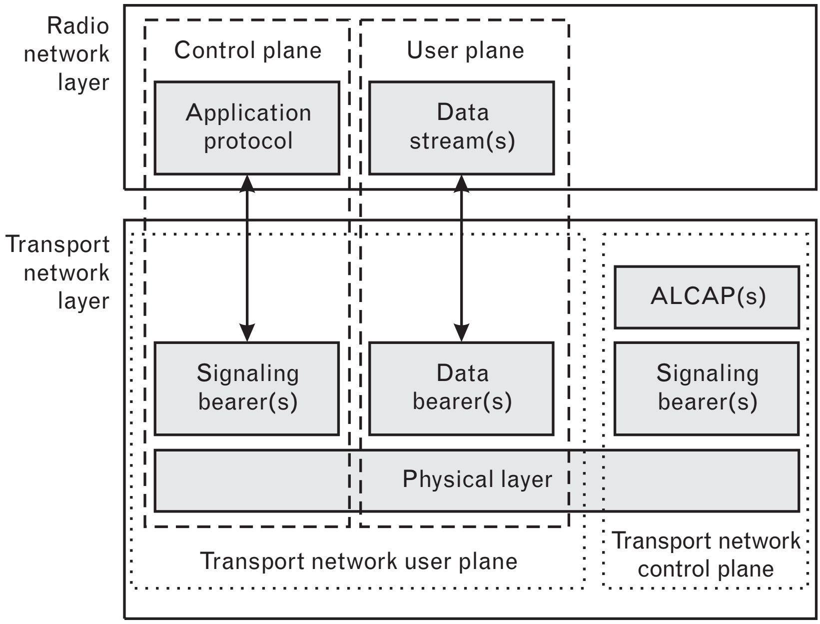


FIGURE 8.9 *General protocol model for UTRAN.*

transfers signaling information, and the user plane transfers application data. This is also the case in the Iu-interface, but this requires some explanation.

In the vertical direction, the Iu-protocol model is divided into three planes, the (radio network) control plane, the (radio network) user plane, and the transport network control plane. Both radio network layer planes, control and user, are conveyed via the transport network layer using the transport network user plane.

The signaling bearer in the transport network layer is always set up by O&M actions. The signaling protocol for the access link control application protocol (ALCAP) may be the same type as the signaling protocol for the application protocol, or it may be different. Once the signaling bearers are in place, the application protocol in the radio network layer may ask for data bearers to be set up. This request is relayed to the ALCAP in the transport network layer. The ALCAP is responsible for the data bearer setup and it has all the required information about the user plane technology. It is also possible to use preconfigured data bearers, as is done in the Iu-PS interface, in which case no ALCAP is needed. Since the signaling bearer in the transport network control plane is only needed for the ALCAP, the entire transport network control plane is unnecessary in this case.

So what is the purpose of this rather complex protocol model? The complexity strives for the total separation of the control plane from the user plane. If the radio network layer control plane had set up the user plane data bearers by itself, it should have had its own knowledge of the underlying technology and its capabilities. The radio network layer control plane doesn't have to know anything about the transport technology. The bearer parameters it requires are not directly tied to any user plane technology, but they are general bearer parameters. Thus the radio network layer and the transport network layer are logically independent of each other.

As indicated earlier, there are two different physical instances for the Iu-interface (Iu-CS and Iu-PS). The corresponding protocol stacks are given in Figure 8.10 and in Figure 8.11 for the UTRA network. The

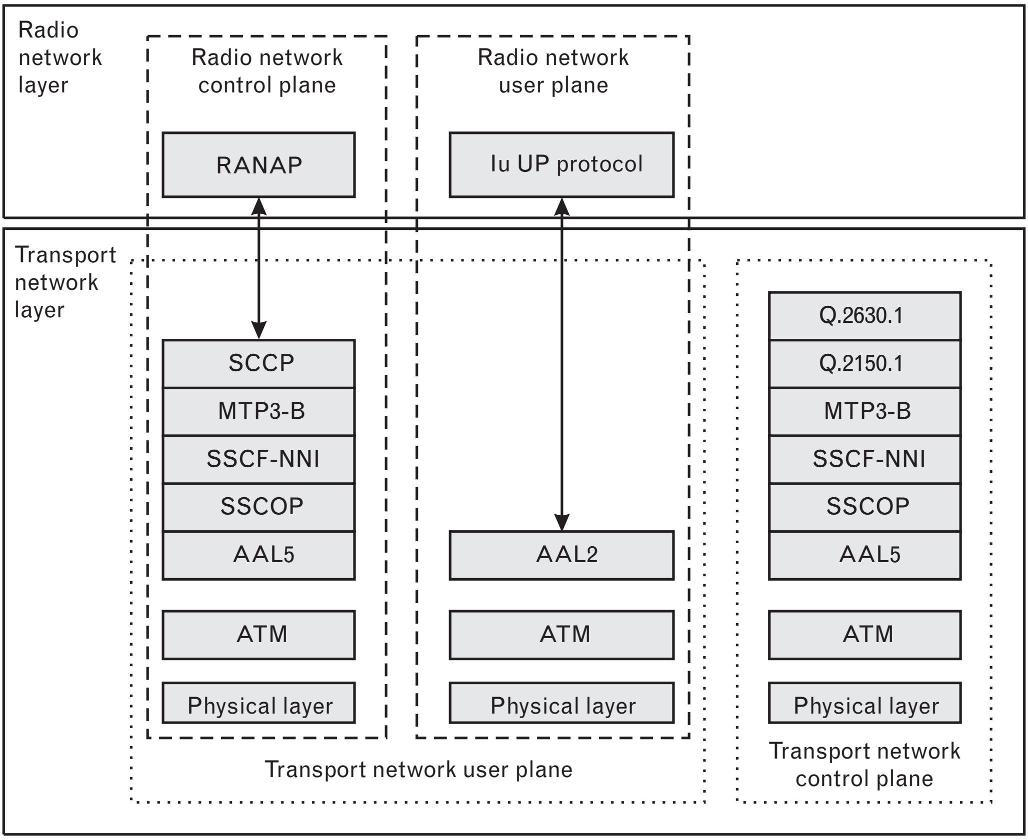


FIGURE 8.10 *Iu-interface/CS domain.*

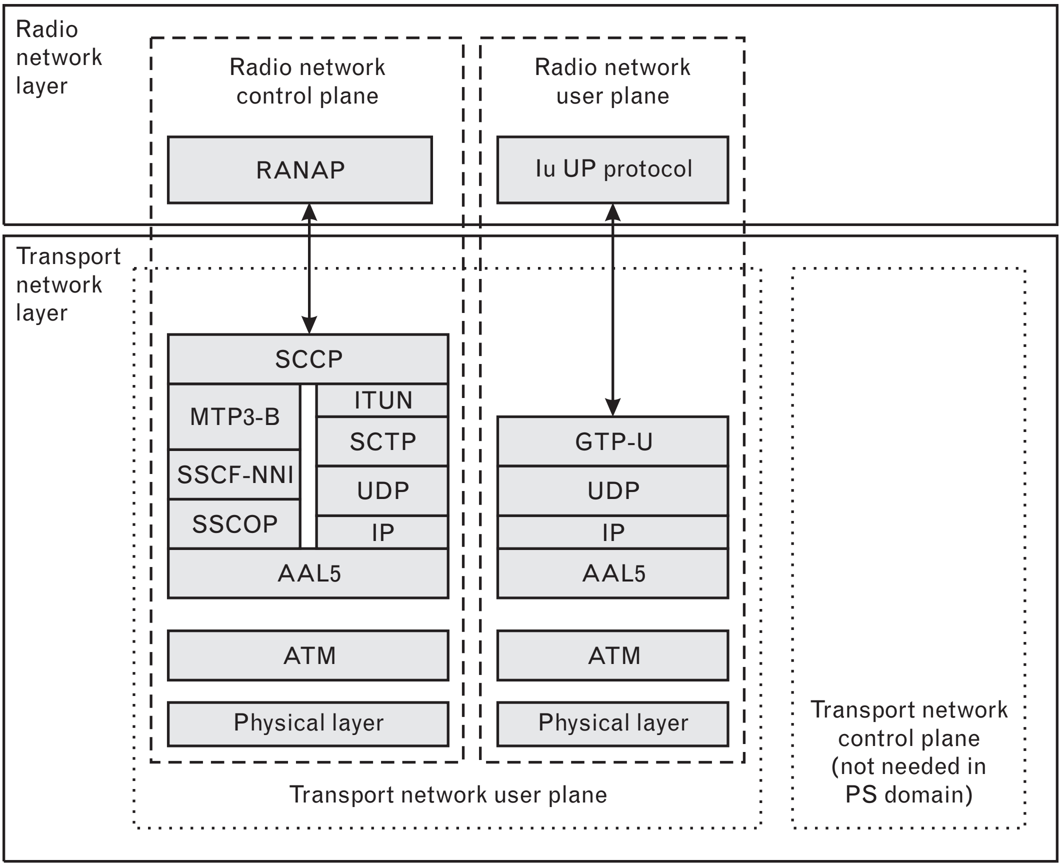


Figure 8.11 *Iu-interface/PS domain.*

various protocols in these stacks are too numerous to be discussed thoroughly, but a short description is given of all of them in the next section.

Both versions of this interface use the asynchronous transfer mode (ATM) transport technology. In the case of the CS domain control plane, there are SS7-based protocols on top of the ATM layers. In the CS domain user plane, only an ATM adaptation layer 2 (ATM AAL2) task is needed to handle the transport of audio and video streams.

In the PS domain control plane, there are two alternative protocol stacks to use. The first one is the same as in CS domain, and the second one is more “IP-oriented.” This version can be used once the data transmission is based on the IP technology (see Section 14.4.6). The user plane in this domain is different from the one in the CS domain. The data packet forwarding is handled by the GPRS tunneling protocol for user plane (GTP-U). The Iu-interface is specified in the 25.41x series of the 3GPP specifications. A good starting point is [13].

8.7.4 Iub-Interface

This interface is situated between the RNC and the Node B in the UTRAN. In GSM terms this corresponds to the A-bis interface between the base transceiver station (BTS) and the base station controller (BSC). The Iub, like its A-bis counterpart, is hardly an open interface. The tasks Node B and RNC have to perform together are so complex that a proprietary solution is the most probable one.

The protocol stack in this interface is based on the same principles as in Iu-interface; there are control and user planes, and a transport network control plane as well. The Iub separates the Node B from the RNC so that none of their internal details are visible over the interface, as this could limit the future expandability of this technology.

The RNC manages Node B(s) over the Iub interface. The following list of functions to be performed over the Iub-interface is presented in [8]:

- Management of Iub transport resources;
- Logical O&M functions of Node B;
- Implementation-specific O&M transport;
- System information management;
- Traffic management of common channels;
- Traffic management of dedicated channels;
- Traffic management of shared channels;
- Timing and synchronization management.

These issues are discussed in connection with the RNC and Node B presentations. See Sections 8.5.1 and 8.5.2. The FP abbreviation in Figure 8.12 stands for "frame protocol."

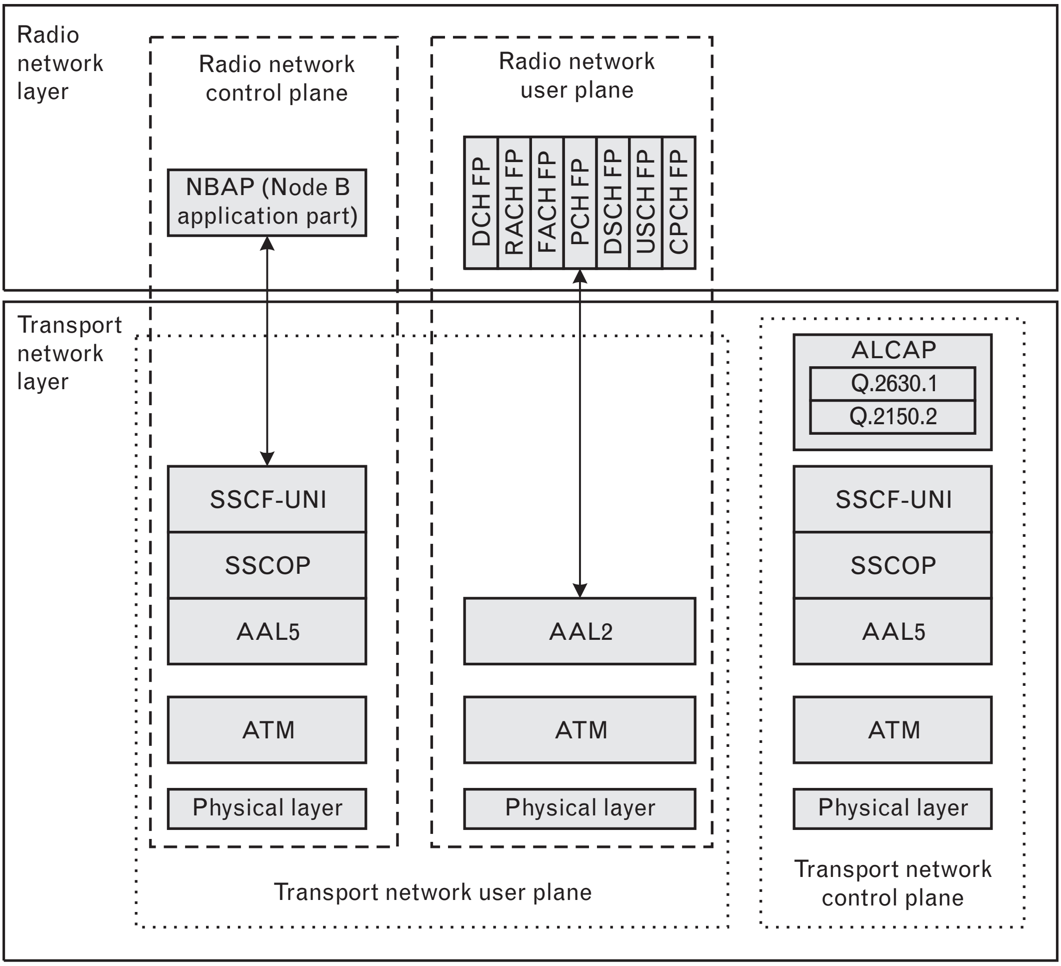


FIGURE 8.12 *Iub-interface.*

8.7.5 Iur-Interface

The Iur-interface connects two radio network controllers. The applicable specification states that this interface should be open, but again only time will show whether this will really be the case. This interface can support the exchange of both signaling information and user data. All RNCs connected via the Iur must belong to the same PLMN. The protocol stack structure is based on the same principles as the Iu and Iub; that is, the radio network and the transport network are separated, so that one of these technologies can be changed without having to change the other.

The Iur interface exists because of macrodiversity. The reader may recall that several base stations can have an active connection with the same mobile station at the same time in a CDMA network. It is possible that these base stations are controlled by different RNCs. Without an Iur interface, this situation would have to be controlled via the Iu interface (i.e., via the MSC), which would be a very clumsy method indeed. Macrodiversity is a purely radio-access-technology-related phenomenon and the MSC should not be bothered with these kinds of issues. The Iur interface is needed so that the UTRAN can manage the problem of soft handovers by itself.

There is always only one RNC, which is in control of a UE connection: this is the managing RNC. This managing RNC is called the serving RNC (SRNC). Any other RNC involved in the connection is a slave RNC, which is called a drift RNC (DRNC). There may be more than one DRNC per UE connection.

An associated concept is the controlling RNC (CRNC). Every Node B is controlled by only one RNC. This RNC has sole control of a group of Node Bs on a UE's behalf. Therefore, this RNC is the CRNC of the Node Bs in a connection. Depending on its role in a connection, a CRNC can also be either a SRNC or a DRNC.

The DRNC handles the macrodiversity combining/splitting of data streams sent via its cells. This means that only one data stream for each UE is needed over the Iur interface. The SRNC can, however, explicitly request separate Iur-interface connections, in which case the macro-combining is done in the SRNC. Those data streams that are communicated via DRNC(s) and the SRNC are combined, or split, by the SRNC.

The power control issues (i.e., the uplink outer-loop power control and the downlink power control commands), are managed by the SRNC, even for those data streams that are communicated via a DRNC.

The signaling information over the Iur interface is transferred using the radio network subsystem application part (RNSAP) protocol; see Figure 8.13. The Iur interface functionality is further discussed in the RNSAP paragraph in Section 8.8. See also [15].

8.7.6 MAP Interfaces

The interfaces between the core network entities are called the MAP interfaces, as they generally use the mobile application part (MAP) protocol as a signaling protocol. The "old" interfaces, which have been

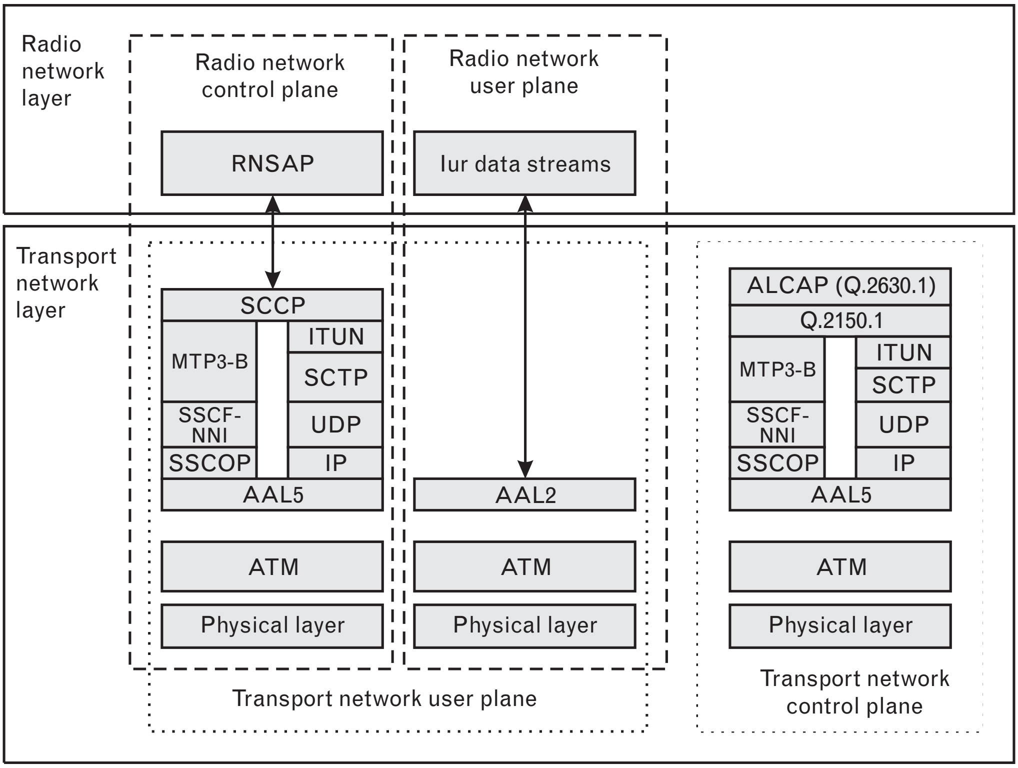


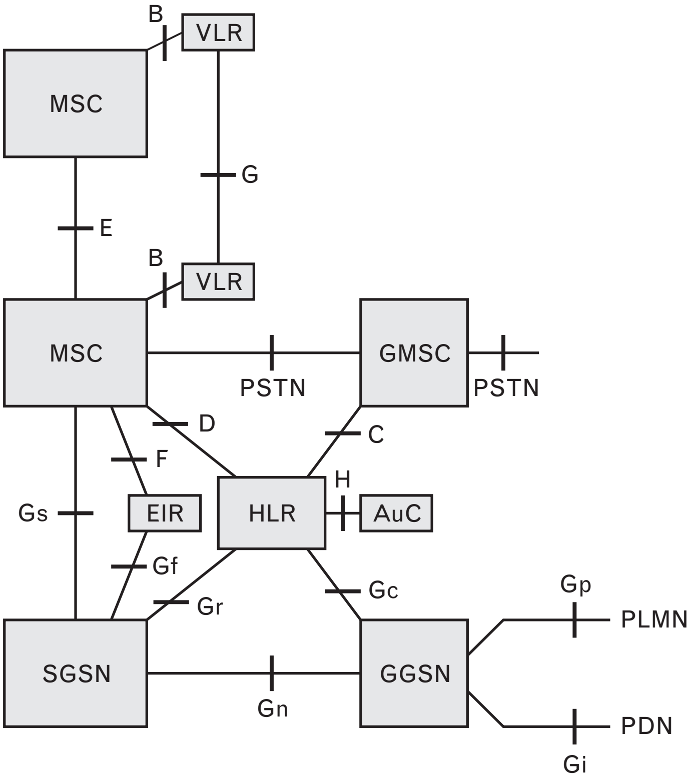
FIGURE 8.13 *Iur interface.*

inherited from the GSM standard, are named with a single capital letter (MAP-A through MAP-M).

The introduction of GPRS into GSM networks brought a batch of new interfaces, which were named using a capital *G* and a small letter. For example, the interface between the SGSN and the HLR is named as Gr (*r* for "roaming"); see Figure 8.14. The meaning of the other "G*x*" interfaces could be described as:

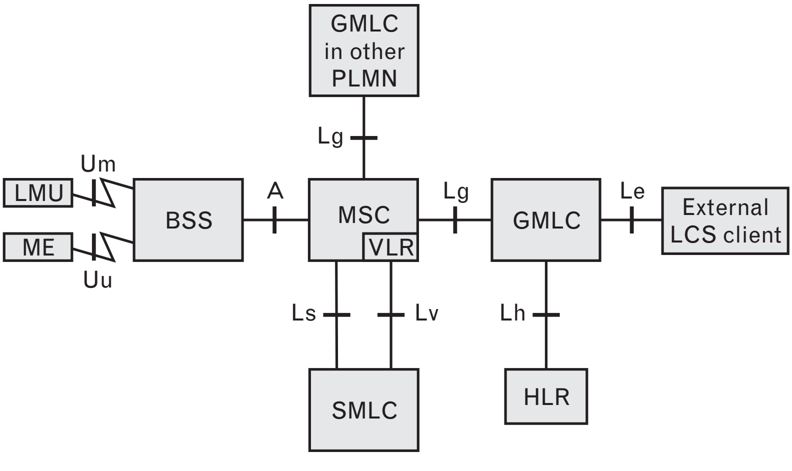
Gf = "fraud" interface
Gi = "Internet" interface
Gp = "PLMN" interface
Gc = "context" interface
Gn = "node" interface
Gb = "base" interface

FIGURE 8.14 *MAP interfaces.*



If location services (LCS) are used in a PLMN, then we will get still more interfaces. These interfaces are named using a capital *L* and a small letter. The LCS interfaces are described in Figure 8.15.

FIGURE 8.15 *LCS network elements and interfaces.*



Most of the interfaces in the core network use the MAP protocol stack for their signaling traffic, but not all. The generic MAP protocol stack is described in Figure 8.16. For example, the topmost protocol layer is named MAP D in the D interface.

Note that this presentation is not a comprehensive one. There are also plenty of other interfaces and their associated details in the core network. The MAP specification [4] itself is a true mammoth. The version 3.3.0, for example, contains well over 1,200 pages. But one has to remember that this specification contains descriptions for all MAP interfaces. A typical MAP protocol is quite simple; it doesn't contain too many messages, and there are only a few procedures. One should not be intimidated by the size of this specification; it is actually quite readable and helps elucidate the inner workings of a PLMN.

8.8 Network Protocols

The network protocols are briefly described below in alphabetical order. This section should be read in connection with the previous section, which describes the interfaces and the protocol stacks used in these interfaces. Because of the number of different protocols in an UMTS network, these descriptions are by necessity rather short. Each protocol description, however, includes references to further sources of information.

The following two figures (8.17 and 8.18) depict the protocol stacks for the control and user planes of the basic line of communications; that is, UE–Node B–RNC–MSC. Note that these pictures describe only one possible implementation of the protocol stacks. For

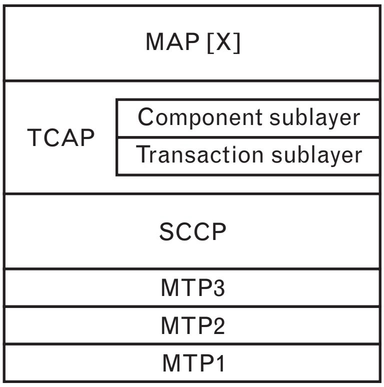


Figure 8.16 *MAP protocols in core network interfaces.*

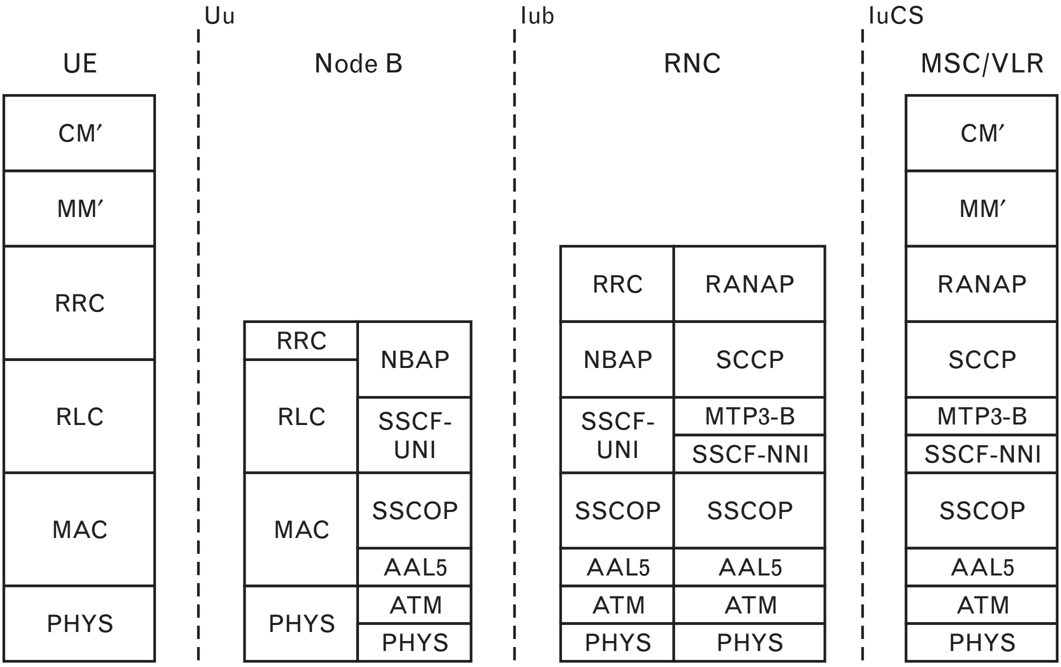


FIGURE 8.17 *Control plane, circuit-switched core network.*

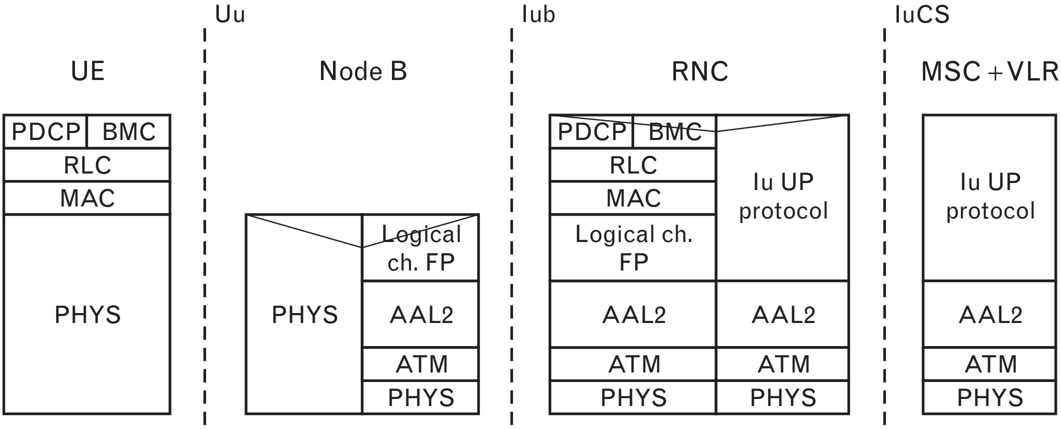


FIGURE 8.18 *User plane, circuit-switched core network.*

example, different channel types often have their own protocol stack variations. Also note that the protocol stack in the Iu interface is different if the UTRAN connects to the PS domain (a connection to an SGSN).

8.8.1 Asynchronous Transfer Mode

The core network transport is based on ATM. ATM is a transmission procedure based on asynchronous time division multiplexing using small, fixed-length data packets. These data packets have a length of only 53 bytes, of which 5 bytes are for the packet header and 48 bytes are reserved for the payload.

The fixed packet[1] length makes it possible to use very efficient and fast packet switches. The chosen packet length (53 bytes) was a compromise between the requirements of speech transfer and data transmission. Filling up long ATM packets with speech samples yields delays, which reduce the quality of real-time speech transmission. Thus the shorter the packet, the better it suits speech transfer. However, pure non-real-time data transfer would be more efficient if longer packets were used. The length of 53 bytes was a suitable compromise, as it allows (near) real-time speech transmission, but doesn't hamper data transmission speeds too much. Also, the 5-byte header doesn't represent too much overhead if the payload is 48 bytes.

8.8.2 AAL2, AAL5

Above the ATM layer we usually find an ATM adaptation layer (AAL). Its function is to process the data from higher layers for ATM transmission. This means segmenting the data into 48-byte chunks and reassembling the original data frames on the receiving side. There are five different AALs (0, 1, 2, 3/4, and 5). AAL Type 0 means that no adaptation is needed. The other adaptation layers have different properties based on three parameters:

- Real-time requirements;
- Constant or variable bit rate;
- Connection-oriented or connectionless data transfer.

---

[1] In ATM jargon, these packets are called cells. To prevent the obvious confusion, this naming convention is not used herein.

The usage of ATM is promoted by the ATM Forum. There are numerous books written about the subject; see [16] for a good example.

The Iu interface uses two AALs: AAL2 and AAL5. AAL2 is designed for the transmission of real-time data streams with variable bit rates. AAL5 fulfills the same requirements except the real-time parameter.

8.8.3 ITUN

ITUN refers to the SCCP adaptation layer, SS7 ISUP tunneling, which is defined in [29].

8.8.4 Iu UP Protocol Layer

This protocol relays the user data from the UTRAN to the CN and vice versa. Each radio access bearer is associated with one Iu user plane (UP) protocol task. This means that there will be several Iu UP protocol tasks allocated for one user if a user has several radio access bearers. These Iu UP tasks are established and released together with their associated radio access bearers.

The Iu UP protocol can operate in two modes:

- Transparent mode;
- Support mode;

The particular mode is decided by the CN when this protocol task is created. It cannot be modified later unless the associated radio access bearer is modified at the same time.

The transparent mode is, as the name indicates, transparent. In this mode the only function of this task is to transfer user data across the Iu interface. No special Iu UP frames will be generated for this transfer, but lower-layer PDUs can be used instead.

The CN creates a support mode Iu UP task if any other particular feature in addition to the ordinary user data transfer is needed. The following functions are possible in the support mode:

- Transfer of user data;
- Initialization;
- Rate control;

- Time alignment;
- Handling of error events;
- Frame quality classification.

In support mode, a special Iu UP frame is created to relay the user data across the Iu interface. The Iu UP protocol is described in [27].

8.8.5 GTP-U

GTP-U stands for the GPRS Tunneling Protocol-User. GTP is the protocol between GPRS support nodes (GSNs) in the UMTS/GPRS backbone network. It includes both the GTP signaling (GTP-C) and data transfer (GTP-U) procedures. GTP is defined in [30].

GTP is defined for the Gn interface (i.e., the interface between GSNs within a PLMN), and for the Gp interface between GSNs in different PLMNs. Only GTP-U is defined for the Iu interface between the serving GPRS support node (SGSN) in the PS domain and the UTRAN.

On the Iu interface, the Radio Access Network Application Part (RANAP) protocol performs the control function for GTP-U. In the transmission plane, GTP-U uses a tunneling mechanism to carry user data packets.

8.8.6 MAP (MAP-A Through MAP-M)

MAP is actually a set of protocols used by the core network elements for their mutual communication. One could describe the core network as a set of database registers, and the MAP protocol as a database query language. The principles and tasks of the various MAP protocols are well discussed in [3].

8.8.7 MTP3-B

Message transfer part (MTP) provides message routing, discrimination and distribution, signaling link management, and load sharing. Its usage is defined in Q.2210.

8.8.8 Node B Application Part

The Node B Application Part (NBAP) is used to manage the Node B by the RNC via the Iub interface. The NBAP can support several parallel transactions.

The NBAP protocol has the following functions:

- *Cell configuration management*. The RNC can manage the cell configuration information in a Node B.
- *Common transport channel management*. The RNC can manage the configuration of common transport channels in a Node B.
- *System information management*. The RNC manages the scheduling of system information to be broadcast in a cell.
- *Resource event management*. The Node B can inform the RNC about the status of Node B resources.
- *Configuration alignment*. The CRNC and the Node B can verify and enforce that both nodes have the same information on the configuration of the radio resources.
- *Measurements on common and dedicated resources*. The RNC can initiate measurements in the Node B. It is then Node B's task to report back the results of these measurements to the RNC.
- *Physical shared channel management* (only in TDD mode). The RNC manages the physical resources in the Node B belonging to shared channels (USCH/DSCH).
- *Radio link management*. The RNC manages radio links using dedicated resources in a Node B.
- *Radio link supervision*. The RNC reports failures and restorations of a radio link.
- *Compressed mode control* (only in FDD mode). The RNC controls the usage of compressed mode in a Node B.
- *DL power drifting correction* (only in FDD mode). The RNC has to adjust the downlink power level of one or more radio links in order to avoid downlink power drifting between the radio links.
- *Reporting general error situations*.

There are two kinds of NBAP procedures:

- NBAP dedicated procedures are those related to a specific UE in Node B.
- NBAP common procedures are those that request initiation of a UE context for a specific UE in Node B, or those not related to a specific UE.

The NBAP protocol is defined in [18].

8.8.9 Physical Layer (below ATM)

The ATM standard does not dictate any special physical medium to be used with it. The physical layer in the Iu interface consists of physical media dependent (PMD) and transmission convergence (TC) sublayers. There is a wide variety of different standards in [14], which can be used to implement PMD.

8.8.9 Q.2150.1

This protocol task is a converter between the ALCAP and MTP3-B protocols.

8.8.10 Q.2630.1

A generic name for this protocol is access link control application part (ALCAP). It will be used to establish user plane connections toward the CS domain. This is also known as the AAL2 signaling protocol.

8.8.11 Radio Access Network Application Part

The Radio Access Network Application Part (RANAP) is defined in [25]. This is a sizable protocol, comparable to the BSSAP protocol in the GSM system. This protocol deserves a longer discussion, as it is the glue between the core network and the UTRAN.

RANAP provides the signaling service between the UTRAN and the CN that is required to fulfill the RANAP functions described later. RANAP services are divided into three groups:

1. *General control services*. These are related to the whole Iu interface.

2. *Notification services.* These are related to specified UEs or all UEs in a specified area.
3. *Dedicated control services.* These are related to only one UE.

Signaling transport (i.e., the transport network layer in the Iu interface) provides two different service modes for the RANAP:

1. *Connection-oriented data-transfer service.* This service is supported by a signaling connection between the RNC and the CN domain. It is possible to dynamically establish and release signaling connections based on need. Each active UE has its own signaling connection. The connection provides a sequenced delivery of RANAP messages. RANAP is notified if the signaling connection breaks.
2. *Connectionless data-transfer service.* RANAP is notified in case a RANAP message did not reach the intended peer RANAP entity.

The RANAP protocol has the following functions:

- *Relocating serving RNC.* This function enables change to the serving RNC functionality as well as the related Iu resources (RAB(s) and signaling connection) from one RNC to another.
- *Overall RAB management.* This function is responsible for setting up, modifying, and releasing RABs.
- *Queuing the setup of RAB.* The purpose of this function is to allow placing some requested RABs into a queue, and to inform the peer entity about the queuing.
- *Requesting RAB release.* While the overall RAB management is a function of the CN, the UTRAN has the capability to request the release of RAB.
- *Release of all Iu connection resources.* This function is used to explicitly release all resources related to one UE from the corresponding Iu connection.
- *Requesting the release of all Iu resources.* While the Iu release is managed from the CN, the UTRAN has the ability to request the release of all Iu resources from the corresponding Iu connection.

- *SRNS context forwarding function.* This function is responsible for transferring an SRNS (Serving Radio Network Subsystem) context from the RNC to the CN for an intersystem forward handover in case of packet forwarding.
- *Controlling overload in the Iu interface.* This function allows adjusting the load in the Iu interface.
- *Resetting the Iu.* This function is used for resetting an Iu interface.
- *Sending the UE Common ID (permanent NAS UE identity) to the RNC.* This function makes the RNC aware of the UE's Common ID.
- *Paging the user.* This function provides the CN with ability to page the UE.
- *Controlling the tracing of the UE activity.* This function allows setting the trace mode for a given UE.
- *Transport of NAS information between the UE and CN.* This function has three subclasses:
    1. Transport of the initial NAS signaling message from the UE to the CN. This function transparently transfers the NAS information. As a consequence, the Iu signaling connection is set up.
    2. Transport of NAS signaling messages between the UE and CN. This function transparently transfers the NAS signaling messages on the existing Iu signaling connection.
    3. Transport of NAS information to be broadcast to UEs. This function allows setting the NAS information to be broadcast to the UEs from the CN.
- *Controlling the security mode in the UTRAN.* This function is used to send the security keys (ciphering and integrity check) to the UTRAN, and setting the operating mode for security functions.
- *Controlling location reporting.* This function allows the CN to set the mode in which the UTRAN reports the location of the UE.
- *Location reporting.* This function is used for transferring the actual location information from the RNC to the CN.

- *Data volume reporting function*. This function is responsible for reporting unsuccessfully transmitted downlink data volume over the UTRAN for specific RABs.
- *Reporting general error situations*. This function allows the reporting of general error situations, for which function specific error messages have not been defined.

8.8.12 Radio Network Subsystem Application Part

The Radio Network Subsystem Application Part (RNSAP) specifies the radio network layer signaling procedures between two RNCs. The managing RNC in these procedures is called the serving RNC (SRNC) and the slave RNC is called the drift RNC (DRNC).

The RNSAP offers the following services:

- *RNSAP basic mobility procedures*. The basic procedures are used to handle mobility within the UTRAN.
- *RNSAP DCH procedures*. The DCH procedures are used to handle DCHs between two RNSs.
- *RNSAP common transport channel procedures*. The common transport channel procedures are used to control common transport channel data streams over the Iur interface.
- *RNSAP global procedures*. The global procedures are not related to a specific UE. These procedures are different from the other procedures in that they involve two peer CRNCs.

In general, only one RNSAP DCH procedure per UE can be active at any instance in time.

The RNSAP protocol includes the following functions:

- *Radio link management*. The SRNC can manage radio links using dedicated resources in a DRNS.
- *Physical channel reconfiguration*. The DRNC can reallocate the physical channel resources for a radio link.
- *Radio link supervision*. The DRNC can report failures and restorations of a radio link.

- *Compressed mode control* (only in FDD mode). The SRNC can control the compressed mode within a DRNS.
- *Measurements on dedicated resources*. The SRNC can initiate measurements on dedicated resources in the DRNS. This function also allows the DRNC to report the result of the measurements.
- *DL power-drifting correction* [only in FDD mode]. The SRNC can adjust the DL power level of one or more radio links in order to avoid DL power drifting between the radio links.
- *CCCH signaling transfer*. The SRNC and DRNC can pass information between the UE and the SRNC on a CCCH controlled by the DRNS.
- *Paging*. The SRNC can page a UE via the DRNS.
- *Common transport channel resources management*. The SRNC can use common transport channel resources within the DRNS (excluding DSCH resources for FDD).
- *Relocation Execution*. The SRNC can finalize a relocation procedure previously prepared via other interfaces. A relocation procedure merely means that the serving RNC has changed.
- *Reporting general error situations*.

The RNSAP is defined in [26].

8.8.13 Signaling ATM Adaptation Layer

Sometimes AAL, SSCOP, and SSCF are considered as one layer: the signaling ATM adaption layer (SAAL).

8.8.14 Service-Specific Coordination Function

Service-specific coordination function (SSCF) is also referred to as SSCF-NNI in the Iu interface, where NNI stands for "network node interface." This protocol task maps the requirements of the higher layer to the requirements of the SSCOP. Its usage is defined in Q.2140.

8.8.15 Service-Specific Connection-Oriented Protocol

Usage of the service-specific connection-oriented protocol (SSCOP) is specified in Q.2110. The SSCOP defines mechanisms for the connection establishment, release, and reliable exchange of signaling information between signaling entities.

8.8.16 Signaling Connection Control Part

Signaling connection control part (SCCP) is defined in [19–24]. This protocol shall comply with the ITU-T White Book. Here two SCCP message transfer service classes are used: class 0 and class 2. Class 0 provides a connectionless service and class 2 a connection-oriented service. Each mobile has its own signaling link while the connection-oriented service is used.

8.8.17 Simple Control Transmission Protocol

The simple control transmission protocol (SCTP) can transmit various signaling protocols over IP networks. The SCTP is defined in [28].

8.8.18 UDP/IP

User datagram protocol (UDP) is specified in RFC 768. Both the IPv4 and IPv6 shall be supported. IPv4 is specified in RFC 791 and IPv6 in RFC 2460.

REFERENCES

1. Mehrotra, A., *GSM System Engineering*, Norwood, MA: Artech House, 1997.
2. 3GPP TS 23.008, v 3.5.0, Organization of Subscriber Data, 2000.
3. Mouly, M., and M.-B. Pautet, *The GSM System for Mobile Communications,* Published by the authors, 1992.
4. GSM 09.02, version 7.5.1, "Mobile Application Part (MAP) Specification," 2000.
5. 3GPP TS 23.002, v 3.3.0, Network Architecture, 2000.
6. 3GPP TS 29.002, v 3.6.0, Mobile Application Part (MAP) Specification, 2000.
7. Walke, B., *Mobile Radio Networks*, New York: Wiley, 1999.
8. 3GPP TS 25.430, v 3.3.0, UTRAN Iub Interface: General Aspects and Principles, 2000.

9. Silventoinen, M., "Indoor Base Station Systems," in *GSM—Evolution Towards 3rd Generation Systems*, ed. Z. Zvonar, P. Jung, and K. Kammerlander, Kluwer Academic Publishers, 1999, pp. 235–261.
10. GSM 02.56, version 8.0.0, GSM Cordless Telephony System (CTS), Phase 1; Service Description; Stage 1, 2000.
11. GSM 03.56, version 7.1.0, GSM Cordless Telephony System (CTS), Phase 1; CTS Architecture Description; Stage 2, 2000.
12. Johnsson, M., "HiperLAN/2–The Broadband Radio Transmission Technology Operating in the 5 GHz Frequency Band," Hiperlan2 Global Forum White Paper, 1999 http://www.hyperlan2.com/web/pdf/whitepaper.pdf, accessed 1.25.2001.
13. 3GPP TS 25.410, v 3.2.0, UTRAN Iu Interface: General Aspects and Principles, 2000.
14. 3GPP TS 25.411, v 3.2.0, UTRAN Iu Interface Layer 1, 2000.
15. 3GPP TS 25.420, v 3.2.0, UTRAN Iur Interface: General Aspects and Principles, 2000.
16. Kyas, O., *ATM Networks*, 2d ed., International Thomson Computer Press, 1996.
17. Roberts, J., U. Mocci, and J. Virtamo, "Broadband Network Teletraffic," COST 242 report, Springer Verlag, 1996.
18. 3GPP TS 25.433, v 3.3.0, UTRAN Iub Interface NBAP Signalling, 2000.
19. Q.711 (7/96) Functional Description of the Signalling Connection Control Part.
20. Q.712 (7/96) Definition and Function of Signalling Connection Control Part Messages.
21. Q.713 (7/96) Signalling Connection Control Part Formats and Codes.
22. Q.714 (7/96) Signalling Connection Control Part Procedures.
23. Q.715 (7/96) Signalling Connection Control Part User Guide.
24. Q.716 (7/96) Signalling Connection Control Performance.
25. 3GPP TS 25.413, v 3.3.0, UTRAN Iu Interface RANAP Signalling, 2000.
26. 3GPP TS 25.423, v 3.3.0, UTRAN Iur Interface RNSAP Signalling, 2000.
27. 3GPP TS 25.415, v 3.4.0, UTRAN Iu Interface User Plane Protocols, 2000.
28. IETF RFC 2960 "Stream Control Transmission Protocol," R. Stewart et al., October 2000.
29. IETF Internet Draft (i.e. a temporary working document) "SS7 SCCP-User Adaptation layer (SUA)," J. Loughney et al., November 2000.
30. 3GPP TS 29.060, v 3.6.0, General Packet Radio Service (GPRS); GPRS Tunnelling Protocol (GTP) Across the Gn and Gp Interface, 2000.
31. Ojanperä, T., "UMTS Data Services," in *GSM—Evolution Towards 3rd Generation Systems*, ed. Z. Zvonar, P. Jung, and K. Kammerlander, Kluwer Academic Publishers, 1999, p. 338.