# 1

# Reconfigurable Systems in a Heterogeneous Environment

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## 1.1 Reconfigurable Systems in Future Networks

As we look beyond the Third Generation of Mobile Communications, we will experience the integration and intercommunication of existing and future networks together with radio access technologies. The convergence towards an Internal Protocol (IP)-based core network and ubiquitous, seamless access between 2G, 3G, broadband and broadcast wireless access schemes, augmented by self-organising network schemes and short-range connectivity between intelligent communicating appliances, enforces common terminal and network entity platforms (Figure 1.1).

In this 'composite radio environment' where several highly standardised legacy radio transport schemes exist, the medium-term goal would be to develop reconfigurable network and terminal techniques to enable interworking and so deliver diverse and exciting applications using the most appropriate radio access scheme(s). Appropriate in this sense refers to the dynamic choice of access scheme(s) to achieve seamless, uninterrupted delivery to the user, customised to the user needs in terms of content, quality of service (QoS) and cost. In such an environment, vertical handover may take place between different access systems (the cellular layer down to the personal network layer, e.g. Bluetooth), combined with real-time service and resource negotiations to seamlessly achieve the desired QoS. The interworking, mobility management and roaming would be handled via the medium access systems and the IP-based core network.

Thus, one of the key elements in the exploitation of the potential benefits, for example ubiquitous connectivity with improved QoS from a heterogeneous radio network, is the

*Software Defined Radio: Architectures, Systems and Functions.* Edited by M. Dillinger, K. Madani and N. Alonistioti
 ISBN: 0-470-85164-3

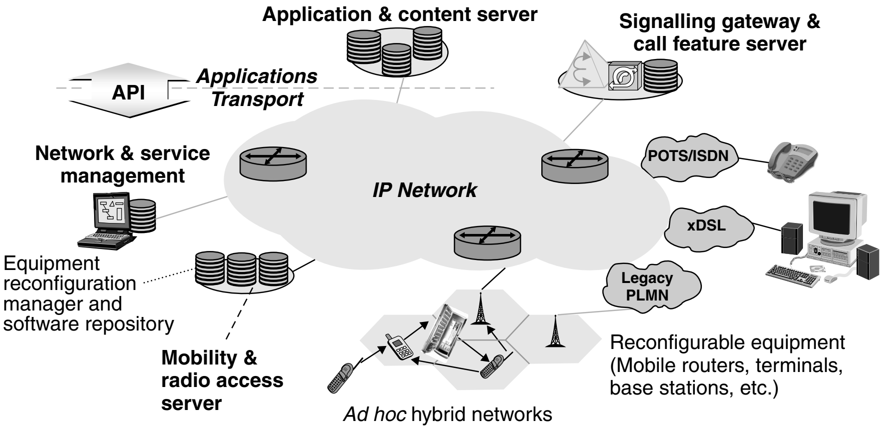


**Figure 1.1** IP-based networks supporting reconfigurable terminals

availability of Software Defined Radio (SDR) terminals with reconfigurable protocol stacks (and its equivalent on the network side).

SDR usually is compared to a radio PC, which can host different air interface applications and the major focus is on the access system. However, it is necessary to broaden the scope and to include all layers for optimising network resources and improving user satisfaction.

However, a challenge for mobile reconfigurable devices originates from the intended flexibility of an open mobile terminal, offering an open software platform. Experiences from the PC platform have shown that the user welcomes the opportunity to install and use third-party software on his system for personalisation issues. This particular feature and the equally reconfigurable protocol software in combination with the traditionally high security demands in communication systems, lead to very complex software systems that need a demanding software security concept. First steps have been undertaken (Java 2 Mobile Edition, MExE) but the increasing complexity and the possibility for complete system reconfiguration are demanding new security and validation concepts. Moreover, currently the proliferation of Java-enabled terminals and the provisioning of multi-mode 2.5 and 3G terminal platforms are also becoming key turning points to more flexible terminals enabled by SDR terminal platforms.

The traditional SDR concept introduces flexible terminal reconfiguration by replacing radios completely implemented in hardware by those that are configurable or even programmable in software to a large extent. These concepts include reconfiguration of the antenna, the radio transceiver and the baseband. Recently, the concept of terminal reconfiguration has been extended, and now includes reconfiguration of applications/services as well as network-based reconfiguration support provided by a dedicated network infrastructure. The reason for this development is that applications/services are likely to be affected by changing transmission quality and changing QoS resulting from vertical handover from one radio mode to another and, therefore, service aspects have to be taken into account in handover decision-making. A network infrastructure providing support for terminal reconfiguration (e.g. for mode detection, mode monitoring, handover decision-making, software download) can increase the performance of vertical handovers or other bearer service adaptations and, at the same time, release the terminal from tasks that are computationally demanding and therefore may negatively affect the performance of active services.

Systems supporting that extended notion of reconfiguration require a clear software architecture that integrates the many layers and functions and offers a reasonable function split between terminal and network infrastructure. The architecture has to be both open and flexible, allowing the exchange of existing functionality as well as integration of new functionality in order to keep pace with the rapid development of terminals and radio technology. User and operator demands as well as regulatory requirements have to be taken into account in order to achieve an optimal solution.

Hence we will refer to reconfigurable systems as a concept to provide reconfigurable mobile communications systems which aim to provide a common platform for multiple air interfaces, multiple protocols and multiple applications thereby increasing network and terminal capability and versatility by software modifications (downloads). With the proliferation of open Application Programming Interfaces (APIs), software from different vendors can run on proprietary hardware platforms. On such platforms, the air interface protocols and applications are executed under the control of a common software environment.

Reconfigurability therefore affects virtually all communication layers (from the physical layer to the application layer) of the radio interface and impacts both the mobile terminal and the radio access networks.

Figure 1.2 shows an example of an all-IP heterogeneous mobile access communications network architecture supporting reconfigurable terminals. The reconfiguration of the layers of the protocol stack may be supported by Home (in the IP backbone) and Local Reconfiguration Managers (in the radio access networks). Note that several

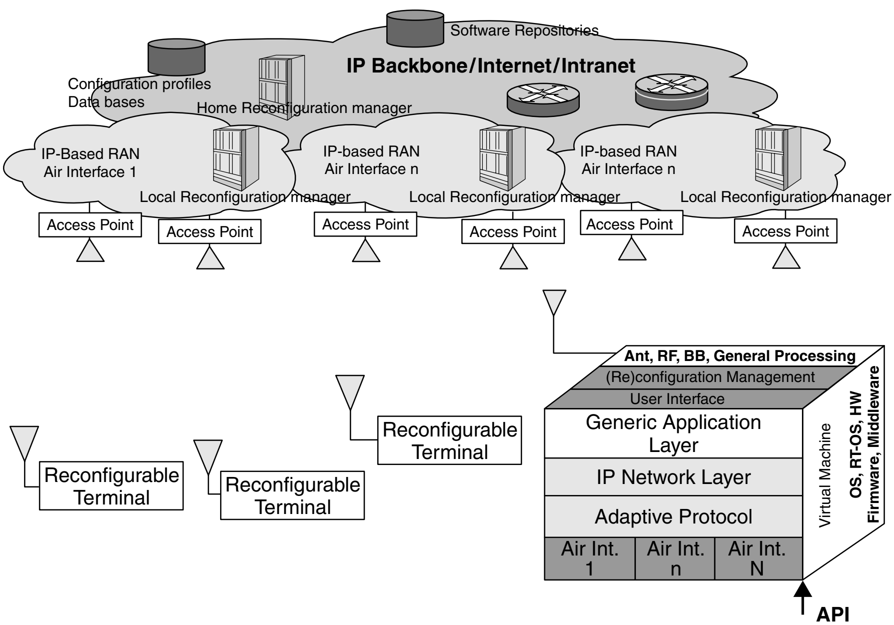


**Figure 1.2** Communications layers subject to reconfiguration in the terminal

functions of these reconfiguration managers may be further defined, as is done below in Section 1.1.10. The layered functional architecture in Section 1.1.10 is mainly derived from the TRUST/SCOUT architecture [1].

### *1.1.1 Key Objectives and General Requirements for Reconfigurable Systems*

As key objectives, reconfigurability should provide the means for:

- Adaptation of the radio interface to varying deployment environments/radio interface standards.
- Provision of possibly new applications and services.
- Software updates.
- Enabling full exploitation of flexible heterogeneous radio networks services.

The provision of SDR poses requirements on the mobile communication system, which fall into three distinct groups:

- Radio reconfiguration control.
- Creation and provision of services to reconfigurable terminals over converging networks and different radio access modes.
- User environment (user profile, terminal, access network(s), and location) management.

Moreover SDR should consider and take into account appropriate security functions that allow reliable operation and avoid any potential abuse despite the high flexibility provided by SDR.

### *1.1.2 Radio Reconfiguration Control*

The reconfiguration control has to provide the following functions:

- Radio access mode identification, blind and assisted.
- Radio access mode switching management.
- Simultaneous connection to multiple services in a heterogeneous radio network environment.
- Secure software download including authentication, hierarchical capability exchange and integrity assurance.
- Efficient algorithms to realise flexible, robust radio access schemes.
- Flexible, reconfigurable terminal/base station software and hardware architectures.

### *1.1.3 Creation and Provision of Services over Converging Networks and Different Radio Access Modes*

The fast creation and provision of (scalable) services is a prerequisite for reconfigurable radio systems. This requires the possibility to activate/download temporarily or over longer time periods protocols, applications or even complete services. These applications and services should

- be independent from the underlying network technologies, environment and traffic conditions; and

- adapt to different underlying network technologies, environments and/or traffic conditions.

The adaptation to different underlying network technologies may require the possibilities to download and activate corresponding protocol stacks to network entities and into the terminal.

### *1.1.4 User Environment Management*

User environment management with respect to SDR is the functionality to match a user profile to the present capabilities of the terminal, network and/or radio interface. The user profile may be stored in a database in the network and/or in a user identification module of a terminal. The user environment management tries to provide adaptively to the user always the same or variable service environment (services, applications, QoS, etc.) depending on the user preferences, the time and/or the location, as far as it can be supported by the capabilities of the terminal, network and radio interface. If these capabilities exceed the user profile, the provided services will be limited to the user profile.

### *1.1.5 Logical Architecture for Reconfigurable Systems*

The logical architecture has to support the following functions:

- Management of the terminal, user and service profiles in the network entities and the terminal.
- Efficient download control and reconfiguration management for terminals and network entities.
- Negotiation and adaptation functionalities for services and Radio Access Technologies (RATs) (e.g. vertical handover); see, for example, ref. [2].
- Assurance of standard compliance.

These functions are logical functions, i.e. they can be implemented in different places in the network. Moreover, they can be distributed within the network and between the network and terminal.

### *1.1.6 Constraining Considerations*

Owing to their great flexibility and to the possibility to change nearly all parameters of the radio interface or higher layer parameters (e.g. parameters in the transport layer), reconfigurable systems are potentially subject to standardisation if mixed operations (a mix of different hardware and software vendors) and open API's between modules are required.

Related topics to be considered are, for example:

- Security functions for reliable and trusted software download (e.g. software download limited to manufacturer approved builds available only from a manufacturer's secure server to protect the manufacturer's regulatory liability for system integrity).
- For the terminal: separation of functionalities used for applications and for radio-specific software.
- For the terminal concerning new applications and services: request user confirmation before software update to avoid incompatibility with other already installed software.

### 1.1.7 Definition of Reconfigurable Systems

Reconfiguration means supporting different system properties and providing multiple views of functionality. In this sense reconfigurable systems are not only an implementation method but have many consequences for system functions to be addressed in standardisation or manifested in industry agreements. We consider the following characteristics for reconfigurable terminals and network entities:

- *Multi-band.* Multi-band systems support more than one specific frequency band, which is used by a harmonised standard such as the Global System for Mobile Communication (GSM), Digital Enhanced Cordless Telecommunications (DECT) and the Universal Mobile Telecommunication System (UMTS). The Radio Frequency (RF) front-end must be capable of fulfilling the necessary RF specifications and, moreover, must be tunable over a wide range of frequency bands. When considering variable duplex distances in Frequency Division Duplex (FDD) systems, additional complexity is added.
- *Multi-homing.* Conceptually, independent radio standards may be processed simultaneously by the platform and, when using it for a user equipment, a flexible partition of the traffic streams are possible thereby providing better QoS and in general a higher connectivity. In particular, multi-standard base stations must be addressed in this context.
- *Multi-function.* The reconfigurable platforms should be application independent and provide a multi-tasking environment for air interface processes, higher layer protocols and user services and applications.
- *Reconfiguration levels and scenarios.* These can be differentiated according to time and usage and the following reconfiguration types are important to outline:
  - Partial Reconfiguration – this refers to the situation when one or more modules are reconfigured without changing the operating standard, i.e. intra-standard reconfiguration. For example, certain modules may be reconfigured in order to improve QoS whilst remaining at the current operating standard. This is also applicable when only parts of the terminal are being reconfigured (e.g. digital baseband) whilst applications or user interfaces are still active.
  - Total Reconfiguration – this refers to the situation when the signal chain is reconfigured from one standard to another, i.e. inter-standard reconfiguration. For example, from GSM to UMTS. This reconfiguration corresponds to exhaustive changes in the functionality, behaviour and interfaces of the constituent modules.
  - Static Reconfiguration – this refers to when, at the time of manufacture or in off-line mode, new capabilities are programmed by, for example, a smart card or by other means.
  - Background Reconfiguration – this refers to the situation when software is downloaded, installed and initialised at a certain event or time stamp. Usually, this is realised by providing shadow and active modules, or even a complete chain of modules, which are then swapped when user services are terminated.
  - Transparent Reconfiguration – this refers to the situation when software is downloaded, installed and initialised at a certain event or time stamp without impacting current user activities and services.

Its is evident, that transparent reconfiguration in conjunction with adaptive radio multi-homing is the most sophisticated design approach for terminals, and provides the highest QoS, connectivity and user satisfaction.

### *1.1.8 Reconfigurable Terminals in Heterogeneous Radio Network Environments*

Today, it is clear that multimode (multi-RAT) terminals are becoming more and more a *de facto* feature in mobile radio terminals [3]. Typically, at least two or more radio access technologies [e.g. short range such as blue tooth and wide-range such as General Packet Radio Service (GPRS)] are integrated on the same device. In parallel, the proliferation of Java enabled terminals and the provision of multi-mode 2.5 and 3G terminal platforms are also becoming key turning points to any future flexible terminals enabled by reconfigurable terminal platforms, where all the layers will be subject to reconfiguration.

Such a reconfigurable terminal platform is represented in Figure 1.2 on three planes: the hardware and associated operation system plane, the software plane and the management plane. The gluing technologies for the three planes are well defined APIs and Middleware. An API can then be seen as an abstract interface definition, which is not code, a program or application, but a description of the relationships between related software and/or hardware modules, such as bi-directional flow of data and control information. It describes the relationship between modules, not the implementation of those relationships. The interfaces should be independent of the implementation. Middleware technology, very popular in the Information Technology (IT) domain, can be seen as an enabling layer of software that resides between the application and the networking layer of heterogeneous platforms and protocols. It decouples applications from any dependencies on the underlying layers, which consist of heterogeneous operating systems, hardware platforms and communication protocols.

### *1.1.9 Functional Abstraction Layers between the Mobile Radio Heterogeneous Entities and the Reconfigurable Terminal*

Given that all the layers of the protocol stack are subject to reconfiguration, the functional interface between the terminal (which could also be assumed to be distributed, functionally

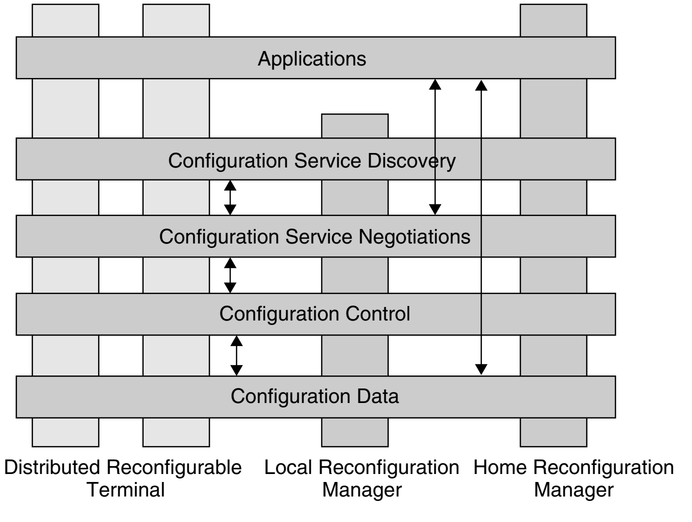


**Figure 1.3** Example of functional interfaces between the different open platform entities in a mobile access network

or physically), the radio access networks and the core network entities need to be devised adequately in order to fully benefit and also minimise the burden, in the context of open platforms (terminals and radio access network entities).

Several of these abstraction layers – configuration service discovery, negotiations, configuration control and data – are shown in Figure 1.3. Moreover, one can imagine interactions between the abstraction layers in order to further optimise the configuration and usage of the open platforms. Note also that given the potential burden introduced by the flexibility provided by open platforms, a management policy based on user, terminal, radio access networks profiles and location is a means to minimise the complexity of such reconfigurable radio terminals and networks. These profiles and policies are stored in corresponding databases in the terminal, radio access networks or core network.

## 1.2 System Functions for Reconfigurability in Mobile Networks

The discussion of a specific reconfiguration support functions for reconfigurable terminals in this chapter is based on the general overall structure of (cellular) mobile networks. It is assumed that the cellular network serving as a reference network in which other RATs are integrated has a clear separation between the Radio Access Network (RAN) and the Core Network (CN), as shown in Figure 1.4. These may be regarded as separate layers with a defined interface. This separation is realised by the current UMTS architecture, as demonstrated in [4], where an idealised architecture for the UMTS network is displayed. It clearly shows the separation between the RAN and the CN:

- The RAN contains radio-technology-specific entities such as the Radio Network Controller (RNC) and the Node Bs, and takes care of tasks such as radio resource management and other access stratum functions.
- The CN hosts entities such as the Mobile Switching Centre (MSC) and the Gateway Mobile Switching Centre (GMSC) for the circuit-switched domain or the Service GPRS Support Node (SGSN) and Gateway GPRS Support Node (GGSN) for the packet-switched domain. The core network is responsible for call management and for establishing connections between participants.

We now focus on a single operator scenario in which a single operator offers different RATs to its customers. These different RATs will be integrated into the operator's cellular network. Several scenarios are conceivable how this integration is done. For the present investigation, we assume that it is most likely that a common core network is used in which several RANs are integrated. However, also types of couplings are possible that require only a loose integration between these RATs, which therefore remain essentially independent networks without a common infrastructure. Last, but not least, the coupling depends on the types of RATs that are to be integrated.

Regardless of the chosen type of coupling of the different RATs, the additional requirements for the support of reconfigurable terminals and the extended flexibility provided by handovers between different RATs, in particular consideration of the additional parameters in decisions concerning handovers, requires a specialised infrastructure that provides the necessary support in the network that is beyond the capabilities of the currently deployed network entities.

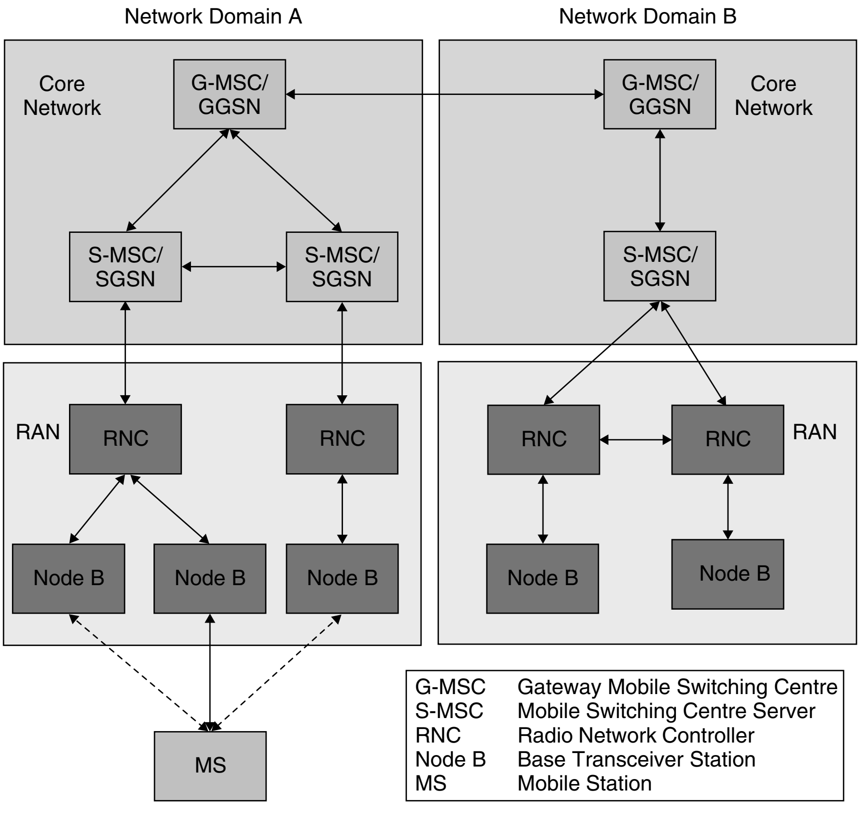


**Figure 1.4** UMTS network architecture

For the inclusion of additional functions related to reconfigurable terminals, however, some functions have to be added.

- Handover management is already available at all entities, as shown in [5]. At the G-MSC it is required only if handover to external networks is to be performed (see, for example, in [7]). MSC/SGSN and RNC are regularly involved (depending on the scenario) in horizontal handover management in UMTS.
- Mode filtering and mode monitoring are done by the mobile station and the RNC (see, for example, in Figure 1.16 [6]).
- The handover decision function is located at the RNC.
- The access stratum function which provides radio layer parameters such as, for example, measured link layer parameters to assess the quality of the connection.

Compared with the functionality required for the full support of reconfigurable terminals, these functions are, however, very restricted and only comprise a small part of the functionality required for reconfigurable terminals.

Starting with the mobile station, the functions in the UMTS and the required extensions are discussed. The access stratum functionality is realised to a great extent in UMTS terminals. It provides the interface to all access stratum parameters; in particular it takes care of signal strength measurements and thereby provides the input parameters for the handover decisions. For reconfigurable terminals, however, considerably improved measurement capabilities are required in order to cope with the variety of simultaneously available radio networks.

Mode monitoring is of course available to detect the different possibilities available for initial cell selection, for instance, but its scope is restricted compared with reconfigurable terminals, as the number of possible RATs for 2G or 3G terminals is fixed. This also applies to mode filtering, a prime task being the ranking of available modes. For 2G/3G terminals, different RATs are usually ranked using a list of allowed Public Land Mobile Networks (PLMNs) and a priority list of PLMNs. For reconfigurable radios a more flexible scheme is used taking into account user preferences.

Handover management is restricted to providing the functionality to change a serving cell, if ordered by the network. It does not really involve decisions by the mobile station itself but just performs network driven handover procedures since it concentrates on horizontal handovers. The ability of the terminal to initiate a handover processes on its own, however, is missing.

The overall picture essentially applies to the functions located at the other entities. Only the mode negotiation function located at the RNC requires additional attention. It is the least developed among the different functions already presented for UMTSs. In the case of vertical handover between GSMs and UMTSs, it takes care of the mapping of bearer services between RATs. However, it does not involve active negotiations, as the properties of the different bearers are fixed and known. Of importance, however, may be the availability of resources in the target network, as some multimedia calls may not be handed over due to a lack of resources. The present approach for UMTSs, however, does not explicitly negotiate this beforehand, but implicitly takes care of this problem if a handover request to the target network fails by attempting a handover to another target cell.

### *1.2.1 Reconfiguration Support Architecture*

Reconfiguration management for reconfigurable systems, however, requires in particular extended support from the network architecture. It is suggested that the radio network architecture is supplemented by Reconfiguration Support Functions (RSFs), which provide the additional functionality necessary to take into account additional parameters. For the sake of a clear presentation, the RSFs are treated as separate entities. Deployment within a given network architecture, however, would in general integrate the support functions into existing network entities.

In order to provide the required support from the network architecture for reconfiguration management and vertical handovers in reconfigurable systems, a complementary architecture is considered. It consists of RSFs that provide the additional functionality required for improved handover support. This architecture mirrors the layer structure of the cellular network model architecture shown in the preceding section.

Figure 1.5 shows the network located entities for an architecture supporting reconfiguration. According to the separation of layers, the responsibilities of the RSFs are divided:

- At the terminal, the Terminal Reconfiguration Support Function (TRSF) is responsible for issues concerning the capabilities, resources and configuration of the terminal,

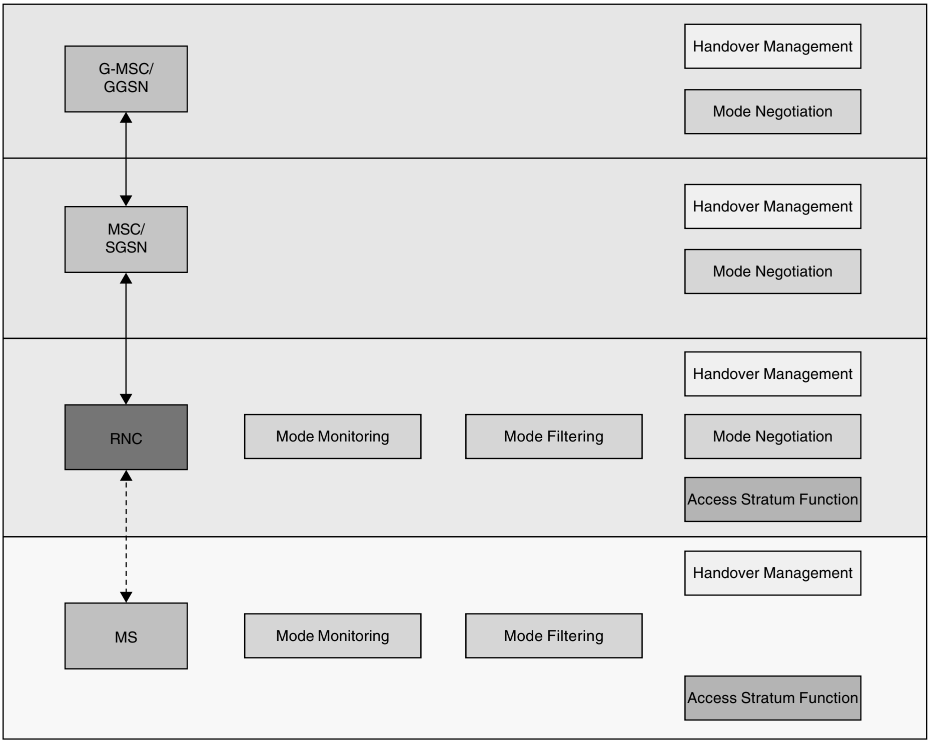


**Figure 1.5** Function distribution in network architecture

terminal-based mode monitoring and, in particular, QoS monitoring and the reconfiguration of applications.

- In the RAN the RAN Reconfiguration Support Function (RRSF) is located at the entity responsible for radio resource management. For instance, in a UMTS, the RNC is the deployment site.
- In the core network, the Serving Reconfiguration Support Function (SRSF) would be situated at the Mobile Switching Centre (MSC).
- Communication with other networks (inter-operator scenario) is taken care of by the introduction of a Gateway Reconfiguration Support Function (GRSF).

### *1.2.2 Functional Distribution*

The functions of the different types of RSFs are shown in Figure 1.6. It shows the different RSFs and their associated functionalities. According to their different positions in the negotiation scheme and their association with the RAN or core network, they provide different functionalities.

- TRSF is responsible for all tasks concerning the handover management on the reconfigurable terminal. This includes the handling of air interface modes, also called mode management, the generation and processing of triggers, QoS management for active

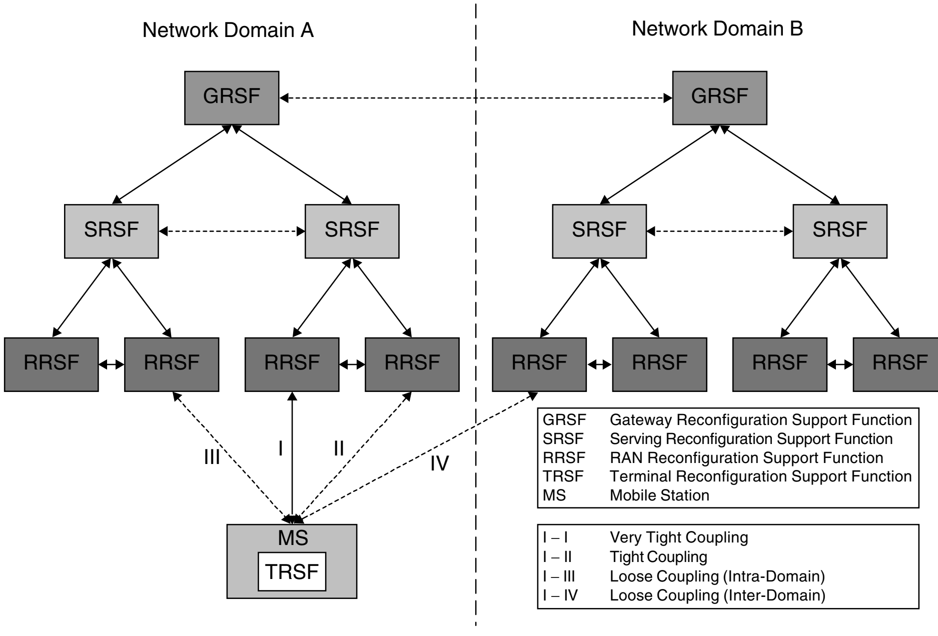


**Figure 1.6** Overview of RSFs and their interactions

services and the decision about the necessity of a handover, the selection of the best suited air interface modes, and the handover execution if required.

- RRSF is the only entity located at the RAN; it provides access stratum functions. Moreover, mode filtering and mode monitoring functions are present. In order to speed up decisions, certain parts of the profile management functions may also be present in the RRSF. Finally, handover management itself is an important function of the RRSF.
- SRSF it contains the general handover management and associated mode filtering and mode negotiation functions. Moreover, context management, profile management and policy management are provided by the SRSF.
- GRSF serves as a gateway to other domains; its functions are restricted to handover management and mode negotiation as far as they are required to perform inter-operator negotiations.

As can be seen from Figure 1.7, some of the functions, e.g. handover management or profile management, are distributed between different reconfiguration support functions. How the involvement of the different functions looks is, however, dependent on the coupling scenario. It determines which entities are involved and which functions on the reconfiguration support functions are used.

### *1.2.3 Network Coupling and Reconfiguration Support*

The integration scheme used for the coupling of two networks determines to a great extent the processes and the RSFs needed for vertical handover. To allow for service continuity and predictable handover behaviour, vertical handovers between different networks require

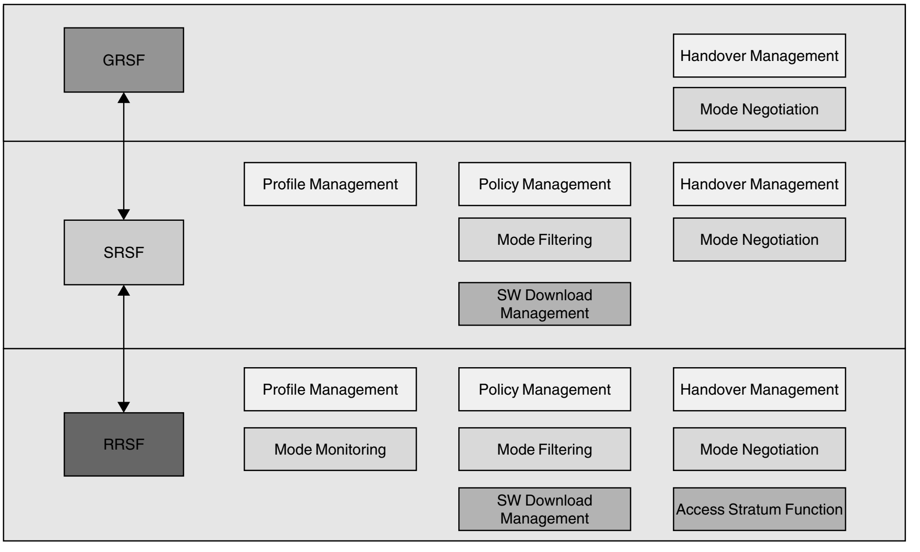


**Figure 1.7** Functions of the RSFs

a connection between the participating networks for handover management. According to the different types of networks that are coupled and depending on the type of coupling, there are different integration schemes [8, 9]. In what follows we assume a UMTS-type cellular network as standard into which other possible networks may be integrated and adopt the UMTS terminology for the entities. In general, four different types of integration/coupling can be distinguished:

- Very tight coupling
- Tight coupling
- Loose coupling
- No coupling

The simplest scheme (no-coupling) requires no integration of the two networks at all. It does not even provide a mechanism for the interchange of information between the networks. All actions have to be coordinated by the mobile station which acts as the only relay for the handover between the two networks. This option is possible for all types of networks; however, information about the new network and the possibility to perform a seamless and reliable handover is very restricted, unless a 'make before break' strategy is employed for handover, which usually requires two radio transceivers.

The other schemes, however, deserve further discussion, as vertical handovers between networks integrated according to the different schemes involve the reconfiguration support architecture in rather different ways.

#### 1.2.3.1 Very Tight Coupling

In the very tight coupling case both networks are integrated at the RAN layer. The entities responsible for both radio access technologies are attached to the same RNC. An advantage of this tight integration is the possibility to establish a common resource management. Information about the usage of both networks is available locally, without having to obtain this information by explicit requests to other entities. Very tight integration is a useful option if the two networks are co-located and have overlapping areas of coverage. Alternatively, a very tight integration is also a reasonable way to integrate local hot-spot networks without a great spatial extension, i.e. their area of coverage is comparable with the area for which the RNC is responsible.

Figure 1.8 shows the participation of the different RSFs in a handover between very tight coupled networks. The RRSF is located at the RNC, which is the common integration point of the two networks. The handover negotiations can therefore be restricted to the RRSF and the MS. SRSF participation is only required if additional information not available at the RRSF is required, for instance if some profile information stored in the SRSF is required for the decision.

Among the advantages of the very tight coupling scheme is the limited number of entities required for vertical handovers. Moreover, a great deal of information needed for

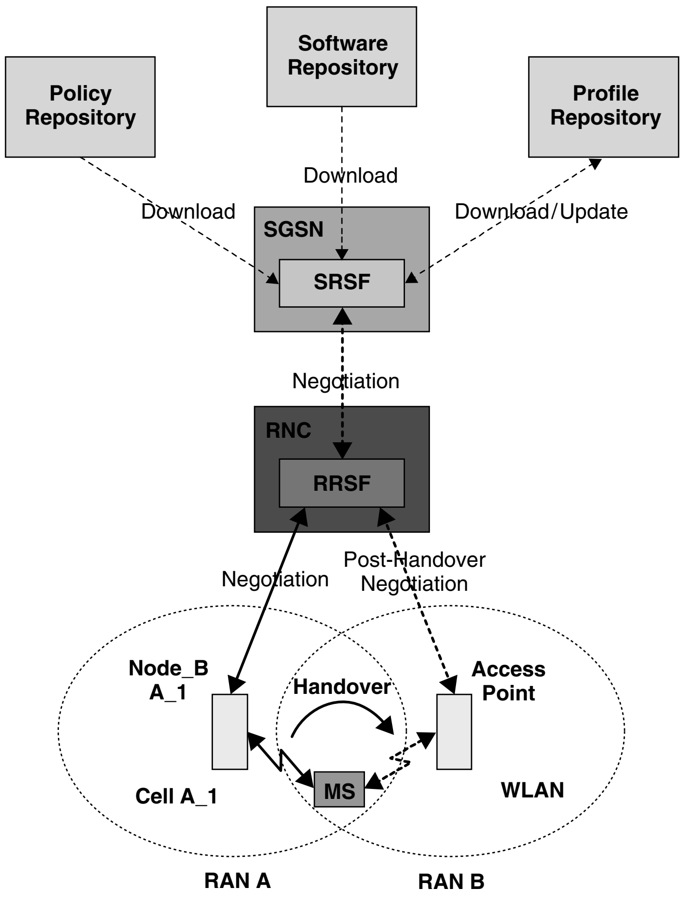


**Figure 1.8** RSFs in a very tight coupling scheme

the decision process is at hand. Therefore delays are reduced to a minimum with this coupling variant.

An additional task of the RSFs is to provide an infrastructure for the provision of software downloads required for the configuration. The figure shows the most extended download path leading via the RRSF and the SRSF to a software download server. By local caching on the RSFs this path may be shortened. In particular it is conceivable that the software for a common terminal is stored at the RRSF, thereby again reducing the reconfiguration time.

#### 1.2.3.2 Tight Coupling

The tight coupling scheme integrates two networks at the RAN layer, as is done in the very tight coupling scheme. However, it uses two different RATs working together with a single core network. The coupling point is the MSC [or the SGSN for the Packet Switched (PS) domain], to which both RANs are attached. In contrast to the loose coupling scheme integration between the two RANs is achieved by the existence of a coupling between the RNCs.

This coupling scheme may be applied to the case of co-located networks. A prominent example is the integration of a GSM and a UMTS. In this case both RANs are connected to the same MSC (or SGSN) taking care of the connection management for both networks.

Although this type of integration does not provide the same degree of cooperation as the very tight coupling scenario (e.g. common resource management), the integration is nevertheless sufficient to provide a fast and reliable interworking for vertical handovers.

However, the handover negotiation process, shown in Figure 1.9, is more complex than in the very tight coupling scheme. For serving and target network there are different responsible RRSFs. The Mobile Station (MS) therefore has to negotiate with both of them during the handover decision-making. The only contact point for the MS is the serving RRSF of the current RAN. This RRSF is responsible for contacting the target RRSF and performing the negotiations required between the two entities. Negotiations between the RRSFs are done directly without involving the SRSF making use of the direct connection between the RNCs. The dashed lines between the RRSFs and the SRSF denote negotiations with the SRSF which are only required for retrieving policies, software or profile information.

A more detailed view of the process is shown in Figure 1.10 which shows the parts of the RRSFs that are participating in a handover negotiation and the handover execution. It shows the functions that are needed at the respective locations and the interactions between the functions at different locations. Whereas all functions of the source RRSF are needed, the target RRSF involves only profile management, handover management, mode negotiation and the access stratum function. The other functions are not involved in the negotiation process at the target RRSF, only at the source RRSF.

#### 1.2.3.3 Loose Coupling (Intra-Domain)

Loosely coupled mobile networks in the intra-domain case do not have a connection at the RAN layer. Instead the networks are connected via the core network, i.e. they share

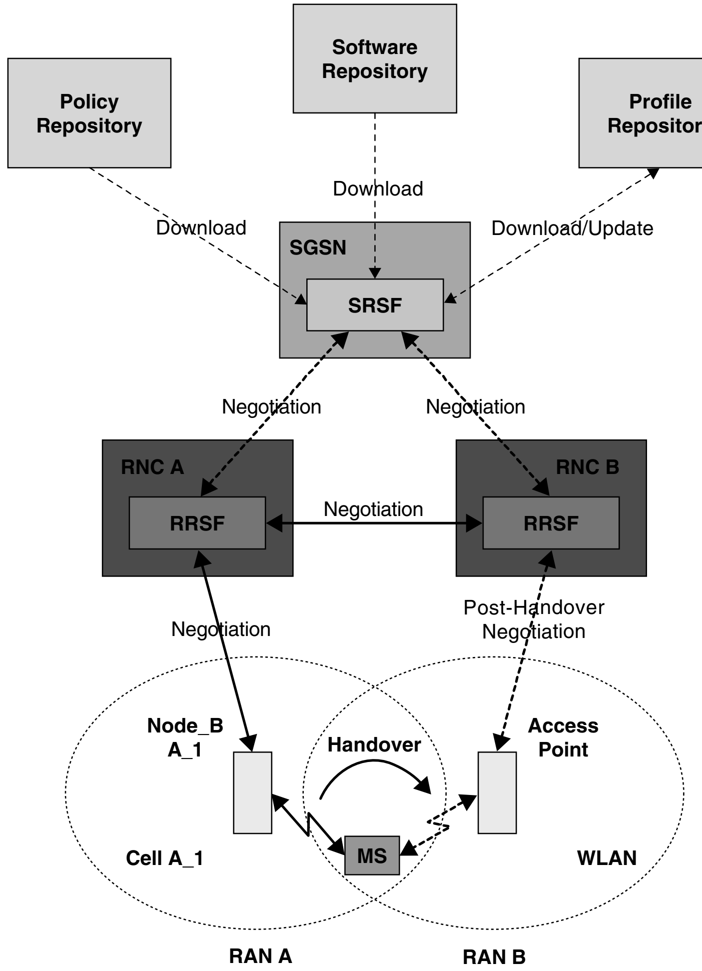


**Figure 1.9** RSFs in a tight coupling scheme

the same core network infrastructure. Figure 1.11 and Figure 1.13 show two different scenarios for intra-domain loose coupling.

Figure 1.11 shows the case when only a single SGSN is involved in the handover. This is the standard case assuming that the responsibilities of the SGSN are divided along geographical lines. As no direct connection between the RNCs is available, the negotiation is done via the SGSN.

A more special case is shown in Figure 1.13 involving the SGSNs. This may occur only rarely, as it is required only if the SGSN area also changes with the handover, but it is nevertheless discussed for the sake of completeness.

The detailed required functionality is shown in Figure 1.12 and in Figure 1.14 for the case of two participating SRSFs. As can be seen from Figure 1.14 the second SRSF's responsibility is mainly to act as a relay between the two networks.

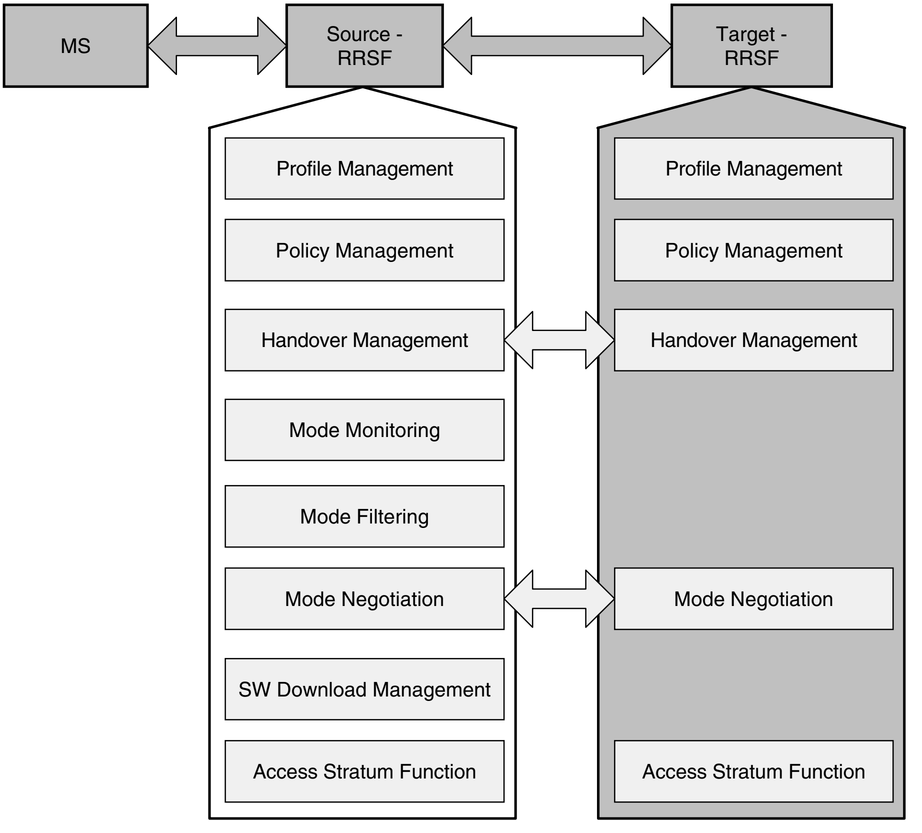


**Figure 1.10** RSFs (functional view) in a tight coupling scheme

### 1.2.3.4 Loose Coupling (Inter-Domain)

Loosely coupled networks offer a common interface for the exchange of information between the networks as required to guarantee service continuity. This may be implemented by a GMSC that takes care of the required interaction. Loosely coupled networks may be either geographically co-located or separated by a geographical boundary. The extent of information available for assessing the necessity and possibility of a handover, however, is restricted. An exchange of information is possible, but requires considerably more time than in the tighter integrated scenarios.

Accordingly, the handover negotiations are considerably more complex compared with the tight and very tight coupling schemes. In this case the complete spectrum of RSFs is involved. The MS starts the negotiation with the RRSF, which performs negotiations with the responsible SRSF, which contacts the GRSF. The GRSF contacts a peer GRSF at the second operator's network, which acts as a negotiation partner for the serving network. The target network's GRSF in turn is responsible for triggering the required reconfiguration using the target network's SRSF and RRSF.

Figure 1.15 shows the participation of the RSFs in this scheme in detail. The main difference compared with the intra-domain scenario (Figure 1.13) is the participation of the

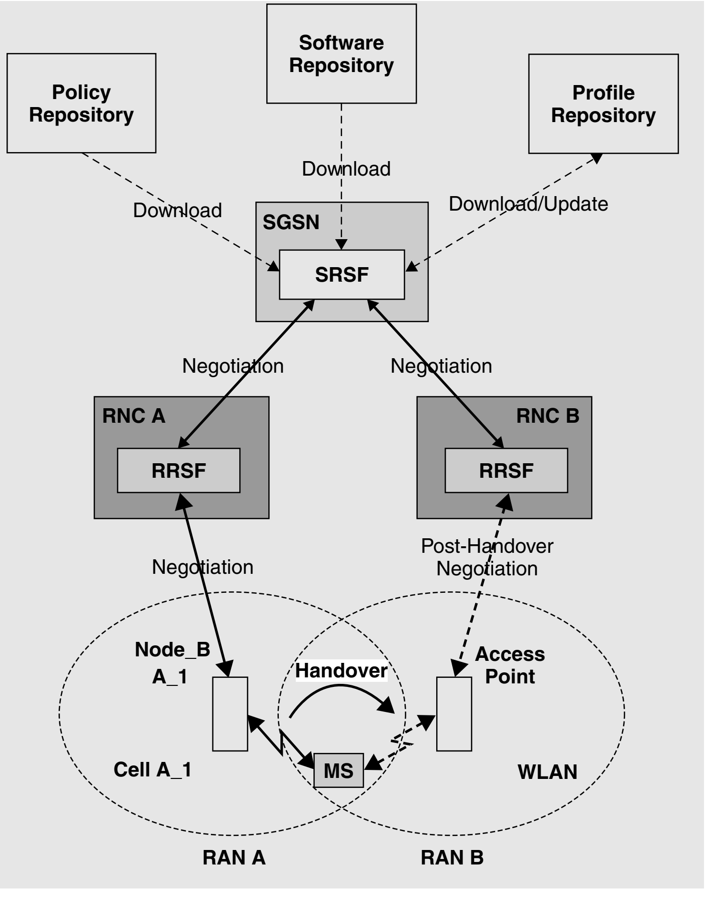


**Figure 1.11** Reconfiguration in an intra-domain loose coupling scheme

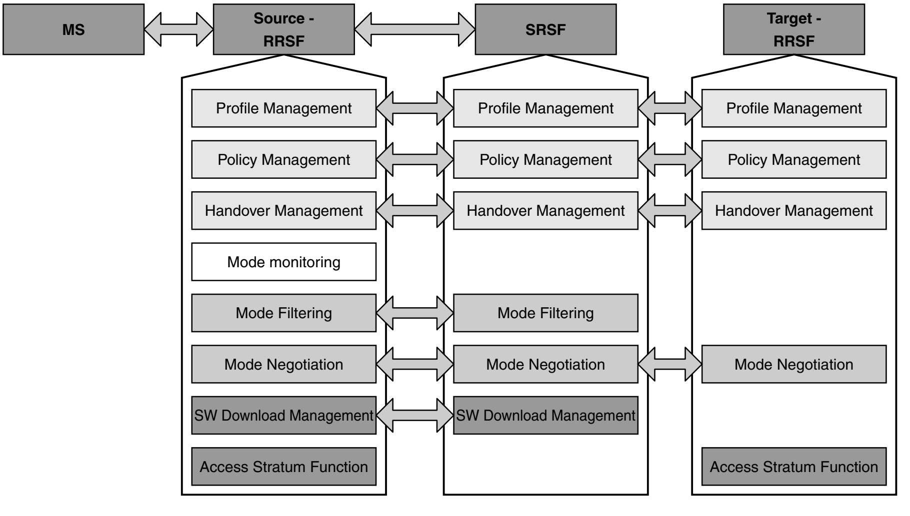


**Figure 1.12** RSFs (functional view) in an intra-domain loose coupling scheme

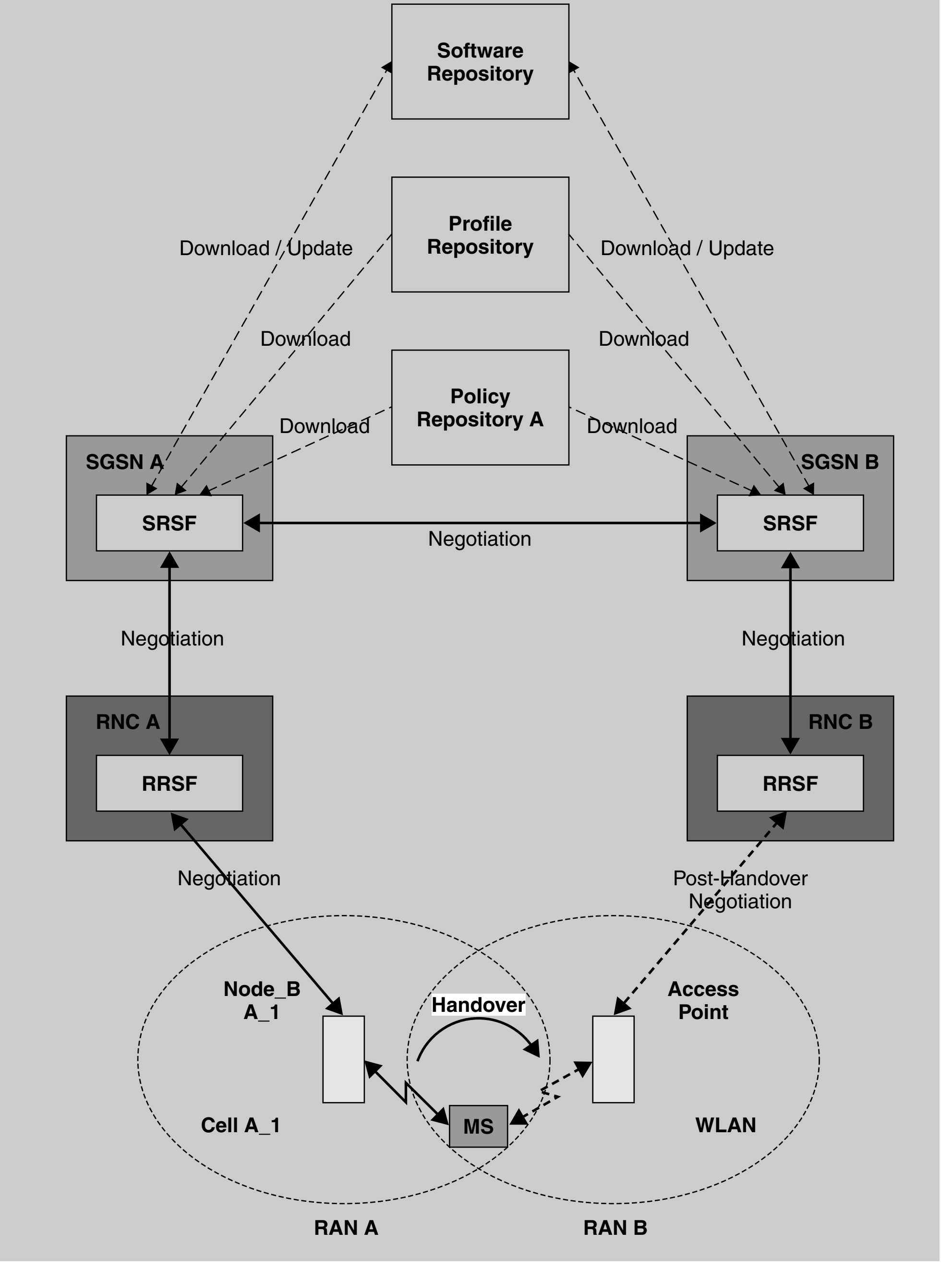


**Figure 1.13** Reconfiguration in an intra-domain loose coupling scheme

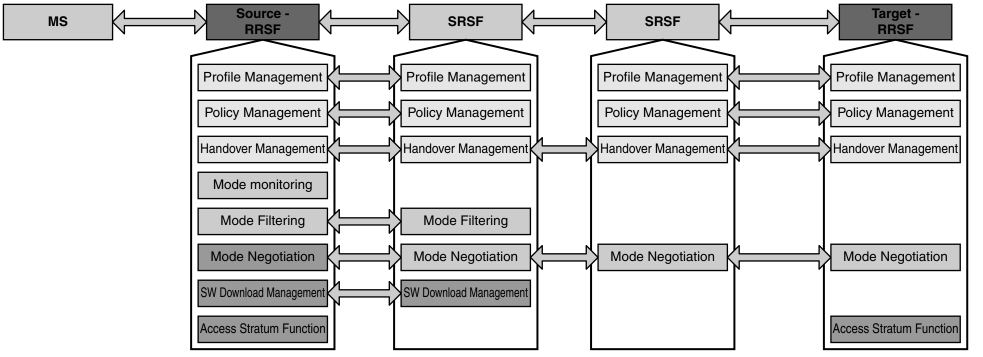


**Figure 1.14** RSFs (functional view) in an intra-domain loose coupling (inter-SRSF) scheme

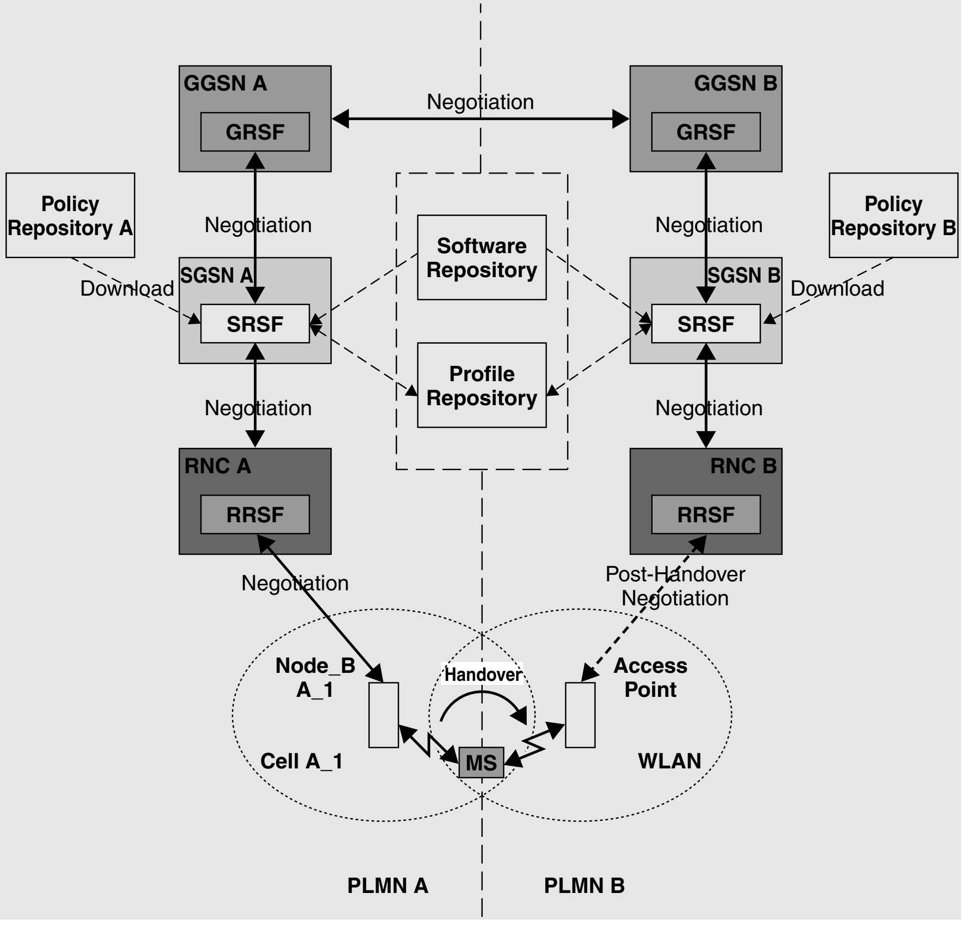


**Figure 1.15** RSFs in an inter-domain loose coupling scheme

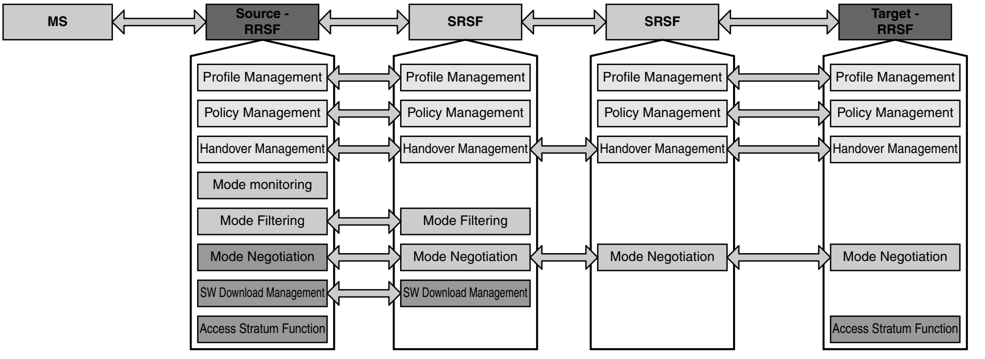


**Figure 1.16** RSFs (functional view) in an inter-domain loose coupling scheme

GRSF, which is necessary for dealing with different networks. As shown in Figure 1.16, the additional entities compared with the intra-domain case deal only with mode negotiation, however only by relaying information or by taking decision on a high layer of abstraction, e.g. whether a mode may actually be used by customers of the particular requesting operator, and handover management.

## Acknowledgements

The authors would like to acknowledge the contributions of colleagues from the SCOUT project, and in particular from Christoph Niedermeier and Reiner Schmid from Siemens AG.

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