Master's Thesis:

Development of a generic model for handover in UMTS

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TECHNICAL SUMMARY

An important functionality, concerning the third generation mobile telecommunications system UMTS (Universal Mobile Telecommunications System), is the handover functionality. To efficiently implement this complex functionality, a model is needed that can handle all possible handover functions (scenarios). The development of such a generic model was the goal that had to be achieved for this project. From this main goal, four objectives were identified that had to be met:

- Analyse the common features of the different handover scenarios;
- Identify and describe the protocols between UMTS network nodes;
- Study and verify the feasibility of a generic model;
- Describe the coverage of the Handover Generic Model.

The analysis of the common features points out that the handover process in UMTS depends on several aspects. These aspects are the handover initiation points, handover initiation procedures, bearer types, the UMTS reference configurations and environments, the handover cases, the handover types, and, finally, the radio interfaces that the network has been equipped with.

Each handover aspect identifies the options that are possible in the particular part of the handover process, during which the aspect is relevant. Because of this, each handover scenario can be described by a combination of options of these handover aspects.

The functionality that is required during a handover is described, using the Handover Functional Model, developed by the MONET (MObile NETworks) project. This model identifies the phases during each handover process and structures the required functionality into Functional Entities.

The handover aspects and their options are used to describe the allocation of the Functional Entities onto the network nodes, the Functional Groups of an example UMTS environment. The possible signalling relations, the protocols, between the Functional Entities and hence between the Functional Groups are described.

The example environment is used to describe the Information Flows that are needed between the Functional Entities. The Information Flows describe the needed interaction between Functional Entities as to support their joint operation. A top-level structure of the handover Information Flows is developed that is suitable for all handover scenarios.

The feasibility of a generic model for the handover functionality in UMTS is studied by formulating SDL (Specification and Description Language) specifications of the Functional Groups of the example environment. The feasibility of such a model is verified by the performance of simulations of the possible handovers, using the simulator in SDT (SDL Design Tool).

Finally, the coverage of the developed Handover Generic Model is described.
During one of his lectures professor J. de Stigter stated he was not sure anymore whether he had chosen the right profession. He feared that the rapid developments in his profession, the telecommunication, would stimulate humanity to become more and more lazy. Because of this statement, among other things, I became interested in the telecommunication. Not because this laziness pleased me, but those rapid developments appealed to me. That's why I asked professor J. de Stigter for a graduation project at the Dr. Neher Laboratories of KPN Research in Leidschendam.

At this moment, my nine month period at KPN Research is almost finished. In this nine month period I have worked at the department Network and Service Control. I have had the opportunity to participate in the European RAINBOW project. I have even attended a three days meeting with the European partners of this project (unfortunately, this meeting took place in Leidschendam).

At this point I would like to thank professor J. de Stigter for giving me the opportunity to fulfil my graduation project at KPN Research and for taking the responsibility of my graduation project. I also like to thank the members of the RAINBOW project who were always willing to spend some time in order to answer all my questions. Especially Marc de Lignie, my daily supervisor, who taught me a lot by making constructive comments and suggestions.

September, 1996
Mart Schoenmakers
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<td>ACTS</td>
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<td>GFP</td>
<td>Global Functional Plane</td>
<td></td>
</tr>
<tr>
<td>GSL</td>
<td>Global Service Logic</td>
<td></td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile communications</td>
<td></td>
</tr>
<tr>
<td>HC</td>
<td>Handover Criteria</td>
<td></td>
</tr>
<tr>
<td>HCA</td>
<td>Handover Criteria Adjustment</td>
<td></td>
</tr>
<tr>
<td>HD</td>
<td>Handover Decision</td>
<td></td>
</tr>
<tr>
<td>HEC</td>
<td>Header Error-Control</td>
<td></td>
</tr>
<tr>
<td>HI</td>
<td>Handover Initiation</td>
<td></td>
</tr>
<tr>
<td>HO</td>
<td>HandOver</td>
<td></td>
</tr>
<tr>
<td>HOC</td>
<td>HandOver Control</td>
<td></td>
</tr>
<tr>
<td>HSE</td>
<td>Handover Security and Encryption</td>
<td></td>
</tr>
<tr>
<td>HUPN</td>
<td>Handover User Profile - Network</td>
<td></td>
</tr>
<tr>
<td>HUPU</td>
<td>Handover User Profile - User</td>
<td></td>
</tr>
<tr>
<td>IF</td>
<td>Information Flow</td>
<td></td>
</tr>
<tr>
<td>IMT2000</td>
<td>International Mobile Telecommunications 2000</td>
<td></td>
</tr>
<tr>
<td>IN</td>
<td>Intelligent Networks</td>
<td></td>
</tr>
<tr>
<td>INAP</td>
<td>IN Application Layer</td>
<td></td>
</tr>
<tr>
<td>INCM</td>
<td>IN Conceptual Model</td>
<td></td>
</tr>
<tr>
<td>ISDN</td>
<td>Integrated Service Digital Network</td>
<td></td>
</tr>
<tr>
<td>ITU</td>
<td>International Telecommunication Union</td>
<td></td>
</tr>
<tr>
<td>ITU-T</td>
<td>ITU Telecommunication Standardisation Sector</td>
<td></td>
</tr>
<tr>
<td>LE</td>
<td>Local Exchange</td>
<td></td>
</tr>
<tr>
<td>MA</td>
<td>Mobile Assisted</td>
<td></td>
</tr>
<tr>
<td>MCN</td>
<td>Mobile Control Node</td>
<td></td>
</tr>
<tr>
<td>MCDN</td>
<td>Mobile CPN</td>
<td></td>
</tr>
<tr>
<td>MEF</td>
<td>Measurement Function</td>
<td></td>
</tr>
<tr>
<td>MEHO</td>
<td>Mobile Evaluated HandOver</td>
<td></td>
</tr>
<tr>
<td>MI</td>
<td>Mobile Initiated</td>
<td></td>
</tr>
<tr>
<td>MO</td>
<td>Mobile Originated</td>
<td></td>
</tr>
<tr>
<td>MNET</td>
<td>MOBILE NETworks</td>
<td></td>
</tr>
<tr>
<td>MS</td>
<td>Mobile Station</td>
<td></td>
</tr>
<tr>
<td>MSC</td>
<td>Mobile services Switching Centre/Message Sequence Chart</td>
<td></td>
</tr>
<tr>
<td>MSCP</td>
<td>Mobile Service Control Point</td>
<td></td>
</tr>
<tr>
<td>MSDP</td>
<td>Mobile Service Data Point</td>
<td></td>
</tr>
<tr>
<td>MT</td>
<td>Mobile Terminal</td>
<td></td>
</tr>
<tr>
<td>N-ISDN</td>
<td>Narrowband ISDN</td>
<td></td>
</tr>
<tr>
<td>NEHO</td>
<td>Network Evaluated HandOver</td>
<td></td>
</tr>
<tr>
<td>NE</td>
<td>Network Entities</td>
<td></td>
</tr>
<tr>
<td>NI</td>
<td>Network Initiated</td>
<td></td>
</tr>
<tr>
<td>NO</td>
<td>Network Initiated</td>
<td></td>
</tr>
<tr>
<td>NS</td>
<td>Network Subsystem</td>
<td></td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>OAM</td>
<td>Operation, Administration, and Maintenance services</td>
<td></td>
</tr>
<tr>
<td>PABX</td>
<td>Private Automatic Branch eXchange</td>
<td></td>
</tr>
<tr>
<td>PE</td>
<td>Physical Entity</td>
<td></td>
</tr>
<tr>
<td>PHP</td>
<td>Physical Plane</td>
<td></td>
</tr>
<tr>
<td>PHT</td>
<td>Public (metropolitan) High Traffic environment</td>
<td></td>
</tr>
<tr>
<td>PHW</td>
<td>Public HighWay environment</td>
<td></td>
</tr>
<tr>
<td>PLT</td>
<td>Public Low Traffic environment</td>
<td></td>
</tr>
<tr>
<td>PSTN</td>
<td>Public Switched Telephone Network</td>
<td></td>
</tr>
<tr>
<td>PSPN</td>
<td>Packet Switched Public Network</td>
<td></td>
</tr>
<tr>
<td>QoS</td>
<td>Quality Of Service</td>
<td></td>
</tr>
<tr>
<td>RACE</td>
<td>Research and technology developments in Advanced Communications technologies in Europe</td>
<td></td>
</tr>
<tr>
<td>RAINBOW</td>
<td>Radio Access Independent Broadband Over Wireless</td>
<td></td>
</tr>
<tr>
<td>RAS</td>
<td>Radio Access System</td>
<td></td>
</tr>
<tr>
<td>RBC</td>
<td>Radio Bearer Control</td>
<td></td>
</tr>
<tr>
<td>RC</td>
<td>Reference Configuration</td>
<td></td>
</tr>
<tr>
<td>RNC</td>
<td>Radio Network Controller</td>
<td></td>
</tr>
<tr>
<td>RRT</td>
<td>Rerouting Triggering</td>
<td></td>
</tr>
<tr>
<td>SBC</td>
<td>Switching and Bridging Control</td>
<td></td>
</tr>
<tr>
<td>SCEF</td>
<td>Service Creation Environment Function</td>
<td></td>
</tr>
<tr>
<td>SCF</td>
<td>Service Creation Function</td>
<td></td>
</tr>
<tr>
<td>SDF</td>
<td>Service Data Function</td>
<td></td>
</tr>
<tr>
<td>SDL</td>
<td>Specification Description Language</td>
<td></td>
</tr>
<tr>
<td>SHRN</td>
<td>Special Handover Request - Network</td>
<td></td>
</tr>
<tr>
<td>SHRU</td>
<td>Special Handover Request - User</td>
<td></td>
</tr>
<tr>
<td>SIB</td>
<td>Service Independent Building block</td>
<td></td>
</tr>
<tr>
<td>SMAF</td>
<td>Service Management Agent Function</td>
<td></td>
</tr>
<tr>
<td>SMF</td>
<td>Service Management Function</td>
<td></td>
</tr>
<tr>
<td>SMS</td>
<td>Short Message Service</td>
<td></td>
</tr>
<tr>
<td>SP</td>
<td>Service Plain</td>
<td></td>
</tr>
<tr>
<td>SRF</td>
<td>Specialised Resource Function</td>
<td></td>
</tr>
<tr>
<td>SSF</td>
<td>Service Switching Function</td>
<td></td>
</tr>
<tr>
<td>TCCN</td>
<td>Target Cells and Connections - Network</td>
<td></td>
</tr>
<tr>
<td>TCCU</td>
<td>Target Cells and Connections - User</td>
<td></td>
</tr>
<tr>
<td>TDMA</td>
<td>Time Division Multiple Access</td>
<td></td>
</tr>
<tr>
<td>TX</td>
<td>Transit Exchange</td>
<td></td>
</tr>
<tr>
<td>UM-HO</td>
<td>Usage Metering Handover</td>
<td></td>
</tr>
<tr>
<td>UM MOC</td>
<td>Usage Meter. Mobile Origin. Call record</td>
<td></td>
</tr>
<tr>
<td>UMTS</td>
<td>Universal Mobile Telecommunication System</td>
<td></td>
</tr>
<tr>
<td>UNI</td>
<td>User Network Interface</td>
<td></td>
</tr>
<tr>
<td>UPT</td>
<td>Universal Personal Telecommunications</td>
<td></td>
</tr>
<tr>
<td>VBR</td>
<td>Variable Bit Rate</td>
<td></td>
</tr>
<tr>
<td>VCI</td>
<td>Virtual Channel Identifier</td>
<td></td>
</tr>
<tr>
<td>VPI</td>
<td>Virtual Path Identifier</td>
<td></td>
</tr>
</tbody>
</table>
In an increasing number of countries, operators are introducing or operating new digital mobile communications networks. Examples of such networks are GSM (Global System for Mobile communications), DCS1800 (Digital Communication System in the 1800 MHz band), DECT (Digital European Cordless Telecommunications) and ERMES (European Radio MEssage System). Compared to the older analog systems, these so-called second generation systems can provide enhanced services to an increased number of users.

The second generation systems are the current answer of the mobile communications industry to the continuing high growth for mobile communications and its more and more demanding users. Though the first second generation systems were implemented only a few years ago, research and development have moved on to the development of third generation systems, like UMTS (section 1.1).

An important problem that has to be solved, concerning UMTS, is the realisation of the handover functionality. The scope of this thesis is the definition of a generic model for this functionality. The motivation and objectives for the development of this model are given in section 1.2. Section 1.3 describes the relation of this study to existing work. The chapter concludes with a survey of the structure of this document.

1.1 Rationale for third generation mobile systems

At the beginning of the next century the mobile communication scene will be significantly different from today. Mobile telecommunications will have become a mass market. People will be used to communicating while on the move. On the demand side, the call for new and more sophisticated services and applications requiring higher bit rates will increase. On the supply side, network operators and service providers will be looking for opportunities to distinguish themselves from their competitors.

These developments will require the introduction of a new generation mobile telecommunications technology that provides the users with a technically integrated, comprehensive and consistent system of personal communications supported by fixed and mobile terminals.

Within the RACE II project MONET (MOible NETworks), research has been performed into the network aspects of the third generation Universal Mobile Telecommunications System (UMTS). UMTS intends to provide a large community of users with a broad variety of services, including present services provided by GSM, DCS1800, DECT and ERMES. A single system will support end-to-end communication with diverse characteristics and bandwidths, through an infrastructure with fixed and mobile components. Present-day developments in Broadband ISDN (B-ISDN), Intelligent Networks (IN) and Universal Personal Telecommunications (UPT) are integrated with UMTS.

At the moment, research is being performed by the Radio Access INdependent Broadband On Wireless (RAINBOW) project. This project investigates
architectural and integration issues through a laboratory implementation of the transport and mobility control functions expected for UMTS.

1.2 Problem identification

An important problem that has to be solved, concerning UMTS, is the realisation of the handover functionality. A handover is a feature, resulting in a change of physical channels, radio channels or terrestrial channels, involved in an association between a mobile terminal and the fixed network while maintaining this association. This functionality is required to support terminal mobility in UMTS.

Within the MONET project, different aspects of the handover functionality have been studied. The handover initiation points are defined by the number of handover initiation points the network has been equipped with. These points gather the information needed for the handover process and determine the need for a handover. The handover initiation procedures define the way the handover process is initiated. The bearer types define the constraints regarding signal quality requirements, synchronisation requirements, and delay requirements. Another aspect that affects the handover functionality is the UMTS reference configuration and environment in which the handover occurs. Handovers between environments can be needed. Depending on the UMTS environment that is involved, different handover cases can occur. The handover cases define which Network Entities are involved during a handover. The handover types define the way the actual switching between bearers is performed. Finally, the handover functionality depends on the radio interface with which the access network of UMTS is equipped. These aspects demand different scenarios to perform a handover. To efficiently implement the handover functionality, a model of the handover functionality is needed that can handle all possible handover scenarios.

The goal of the study described in this report is the definition of such a generic model. In order to reduce the complexity of the handover functionality the following restrictions have been made:

- Switching between radio frequencies (intra BTS handovers) have not been considered;
- Handovers between network providers (inter LE handovers) and handovers between UMTS environments have not been considered;
- The UMTS network that has been considered is a tree topology without interconnections between identical network elements.

Before developing a generic model several objectives have to be met. Firstly, the common features of the different scenarios need to be analysed. The result of this analysis is the identification of handover aspects that apply to these features. Secondly, the protocols needed between Functional Groups have to be identified and described. Thirdly, the feasibility of such a generic model needs to be studied and verified by formulating SDL specifications of a minimum number of processes (Functional Groups). Finally, the coverage of the generic model with respect to the demanded handover scenarios needs to be described and the subjects that need more study will have to be identified.

The project has been carried out at KPN Research as a graduation project for the Eindhoven University of Technology, department of Electrical Engineering.
1.3 Relation to existing work

The study described in this report has taken the results of the MONET project as a starting point.

The Functional Entities of the MONET Handover Functional Model have been used to analyse the way the handover aspects affect the allocation of these Functional Entities onto the Functional Groups.

The logical connections between the Functional Entities, identified by the MONET project have been used to analyse the possible signalling associations between the entities, valid for each handover aspect.

The Information Flows between the Functional Entities, identified by the MONET project have been used to develop a top-level structure of the handover Information Flows that is suitable for all handover scenarios.

1.4 Report outline

Chapter 2 introduces the reader to the architectures of IN, B-ISDN and UMTS. The chapter concludes with a description of the Rainbow project to which the study described in this report is closely related.

Chapter 3 introduces the reader to the concept of handover and identifies the aspects of the handover functionality. This chapter concludes with the presentation of the Handover Functional Model.

Chapter 4 presents the developed Generic Model for handover.

Chapter 5 discusses the allocation of and the logical connections between the Functional Entities of the Handover Functional Model onto the reference configurations of UMTS.

The protocols that are needed to perform handovers are discussed in chapter 6.

The applicability of the Handover Generic Model is discussed in chapter 7.

The last chapter, chapter 8, gives the conclusions and discusses the subjects for further study.
This chapter introduces the reader to the concepts of IN, B-ISDN, and UMTS. The first section (section 2.1) describes the rationale for IN and discusses the four planes of the IN conceptual model. Section 2.2 describes the rationale for B-ISDN and presents the B-ISDN reference configuration and the B-ISDN protocol reference model. The third section (section 2.3) describes the rationale for UMTS and clarifies the relationship of UMTS to IN and B-ISDN. Furthermore, this section introduces the environments to be supported by UMTS and the UMTS reference configuration. The section concludes with a description of second and third generation radio interfaces and supported bearer services that are considered in this study. The chapter concludes with a description of the ACTS RAINBOW project, to which this study is closely related.

2.1 Intelligent Networks

In the early days, customers needing telecommunication services were highly dependent on the telecom operators. Nowadays, with the introduction of the open telecommunication market, this has turned the other way round. Customers are becoming more and more familiar with new technology and demand more sophisticated telecommunication services. Telecom operators have to meet the demands of the customers, because they depend on those customers. This implies that new services have to be introduced.

This is where the problems for today’s telecom operators arise. Their telephony infrastructure is based on switches of different manufacturers. To introduce a new service the telecom operator has to deal with several switch manufacturers, who have to develop new dedicated switch software. Furthermore, all switches have to be adapted to offer the new service. This complicates and slows down the introduction of new services.

The Intelligent Network concept tries to solve these problems by moving the intelligence needed for special services out of the switches into general purpose computer platforms. Telecom operators can now introduce new services by changing or adding new software onto these platforms, and are no longer dependent on the switch manufacturers for the development of new services.

2.1.1 IN Conceptual Model

**Intelligent Network** (IN) is an architectural concept that can be applied to any telecommunication network. The model that captures this concept is called the **IN Conceptual Model** (INCM). It does not specify an architecture of a specific telecommunications network, but specifies the framework for the design and description of any Intelligent Network based network. The concept can, for example, be applied to public switched telecommunication networks, mobile networks, and integrated service digital networks.

The IN Conceptual Model consists of four planes, in which each plane specifies an IN-based network from a different level of abstraction. These planes describe different aspects of an IN-based network. The planes, the elements they contain,
and the relationship between the most important elements of the planes are shown in Figure 2-1.

![Figure 2-1: Intelligent Network Conceptual Model](image)

In the next sections the four planes will be described.

**Service plane**

The *service plane* (SP) describes service related behaviour from a user point of view, in an IN independent way [Q.1202]. No assumptions are made about the IN-based network that has to provide these services. Services are defined in terms of services and service features.

A service is a stand-alone commercial offering, characterised by one or more core service features, and can be optionally enhanced by other service features.

A service feature is a specific aspect of a service that can also be used in conjunction with other services or service features as part of a commercial offering. It is either a core part of a service or an optional part offered as an enhancement to a service.

These two definitions are currently the only things that are described for the service plane. It is not mentioned how a service or service feature should be specified.

**Global Functional Plane**

The *Global Functional Plane* (GFP) models the intelligent network from a global, network wide point of view. The GFP consists of three elements: Service Independent Building Blocks, Basic Call Process, and the Global Service Logic.

The network-wide functions are neither service nor service feature specific and are therefore called *Service Independent Building blocks* (SIBs). SIBs can be used to 'construct' a service. A special kind of SIB is the *Basic Call Process* (BCP) which contains the functionality of handling normal (non-IN) calls. When a special call (an IN call) has to be executed, the BCP passes control to a chain of SIBs that executes the IN-specific part of the call. The SIBs and the BCP SIB are chained together by the *Global Service Logic* (GSL); the GSL can be considered as the 'glue' that links several SIBs and the BCP.
Distributed Functional Plane

The principles of the Distributed Functional Plane are described in [Q.1204, Q.1214]. The DFP gives the distribution aspects of the higher GFP. The elements of the GFP are specified in terms of elements of the DFP. In this way the distribution aspects of the elements of the GFP come visible.

The Functional Model of the DFP, shows the grouping of functions, their relations and actions. A graphical representation is depicted Figure 2-2. The figure shows the allowed relationships between the Function Entities (FEs). The FEs together (or alone) provide the higher level service. The FEs have been given special names analogous to the functions they perform. The meaning of these acronyms and a description of the functions the FEs perform are placed in the legend of the figure.

![Diagram of IN Distributed Functional Plane Model](image)

Legend:
- CCAF: Call Control Agent Function
  - provides access for users to the network
- CCF: Call Control Function
  - provides call or connection processing and control
- SCEF: Service Creation Environment Function
  - allows IN services to be defined, developed, tested and put into the SMF
- SCF: Service Control Function
  - controls the processing of IN services
- SDF: Service Data Function
  - contains customer and network data for real-time access by the SCF
- SMAF: Service Management Agent Function
  - provides an interface between service managers and the SMF
- SMF: Service Management Function
  - allows deployment and provision of IN services and support of the ongoing operation
- SRF: Specialised Resource Function
  - provides specialised resources required for the execution of IN services
- SSF: Service Switching Function
  - the set of functions that invoke IN processing and are required for interaction between the SCF and the CCF

In a normal telephone call, only the CCAF and the CCF entities are involved. The CCAF is the user-interface to the network and the CCF performs basic call handling functions, i.e. routing and sending tones to the user. In the case of an IN-call the SSF ‘recognises’ that IN service processing is required. This recognition can be performed, for example, by analysis of the dialled number or on certain events like ‘called party is busy’.

When the SSF has determined that IN service processing is required, normal call processing is suspended and control is given to the SCF that executes the required service. The SCF can send a query to the SDF, which contains database functions, to return data necessary for the execution of the service. The SCF may also instruct the SRF to play, for example, an announcement to the user or to collect a pincode. The SRF contains specialised resources which are able to perform this kind of functions. When the SCF has finished execution of the service, call control is returned to the SSF. Meanwhile, the SCF may have translated the dialled number into another one, so the call is routed to another destination.

The SCEF, SMF, and SMAF are related to the creation, deployment, provisioning and management of IN services. They have not been standardised yet and will not be discussed here any further.
Physical Plane

The FEs of the DFP can be mapped on the entities in the Physical Plane (PhP) [Q.1205, Q.1215]. The entities in the PhP are called Physical Entities (PEs). The different PEs and the interfaces between them are identified in the PhP.

The PEs contain one or more FEs. In the table below, the most important physical entities are summarised, together with the functionality they (optionally) contain.

**Table 2-1: Scenario of FE to PE mapping**

<table>
<thead>
<tr>
<th>Physical Entities:</th>
<th>Functional Entities:</th>
<th>SCF</th>
<th>SSF/CCF&lt;sup&gt;1&lt;/sup&gt;</th>
<th>SDF</th>
<th>SRF</th>
<th>SMF</th>
<th>SCEF</th>
<th>SMAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSP: Service Switching Point</td>
<td>O</td>
<td>M</td>
<td>O</td>
<td>O</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCP: Service Control Point</td>
<td>M</td>
<td>O</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SDP: Service Data Point</td>
<td></td>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IP: Intelligent Peripheral</td>
<td>O</td>
<td></td>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AD: Adjunct</td>
<td>M</td>
<td></td>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SN: Service Node</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSCP: Service Switching and Control Point</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>O</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMP: Service Management Point</td>
<td>M</td>
<td>O</td>
<td>O</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCEP: Service Creation Environment Point</td>
<td></td>
<td></td>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMAP: Service Management Access Point</td>
<td></td>
<td></td>
<td></td>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend: M = Mandatory
O = Optional

In case two functional FEs need to communicate with each other, the information flows that are defined in the DFP are implemented in the PhP through a standardised Open System Interconnection (OSI)-based application layer protocol, named the Intelligent Network Application Layer (INAP).

<sup>1</sup> Due to the tight relationship between call control and service switching functionality, the SSF and CCF are modelled together. The communication between the SSF and CCF is not subjected to standardisation.
2.2 Broadband ISDN

The Broadband Integrated Services Digital Network (B-ISDN) is a concept for a network aiming at the integration of service for broadband telecommunications, i.e. high speed data communication, video conferencing and multimedia applications.

The International Telecommunication Union Telecommunication Standardisation Sector (ITU-T) adopted the Asynchronous Transfer Mode (ATM) as the transmission technique for B-ISDN. All information to be transferred over an ATM based network is packed in cells of fixed size: ATM cells. ATM is a connection-oriented technique, meaning the network reserves transport capacity through the network for a fixed amount of time. This technique and the asynchronous character of ATM provide a flexible transfer capability common to all services. Connection identifiers are assigned to each link of a connection when required and released when no longer needed. Signalling and user information are carried on separate ATM connections.

2.2.1 B-ISDN configurations

The ITU-T Reference Configuration of B-ISDN is depicted in Figure 2-3. The upper part shows the reference configuration for the case where a B-ISDN user device is connected to B-ISDN. The case that a non-B-ISDN user device is connected to B-ISDN, using a terminal adapter, is shown in the lower part of the figure.

![B-ISDN Reference Configuration](image)

The $S_B$ provides the reference point for the connection of a B-ISDN terminal (B-TE1) to a customer network (B-NT2) whilst the $T_B$ provides the reference point for connection of a customer network to the broadband network termination (B-NT1). The specification of $S_B$ is very similar to $T_B$ although $S_B$ may include access to certain functions which are only available within a customer network or to a private switch. It should also be possible to connect the B-ISDN terminal (B-TE1) directly to the local exchange via the $T_B$ reference point. In this case the reference point is called the coincident $S_B/T_B$ reference point. The $R_B$ provides the reference point for the connection of a non B-ISDN terminal ((B-)TE2) to a B-ISDN Terminal Adapter (B-TA).

2.2.2 B-ISDN protocol reference model

The B-ISDN protocol reference model is based on the OSI reference model and the ISDN standards. Figure 2-4 shows the layers of B-ISDN [Black95, Stallings95].
The B-ISDN model contains three planes: the User Plane, the Control Plane and the Management Plane. The User plane is responsible for providing user information transfer, along with associated controls (e.g., flow control, error control). The Control Plane is responsible for setting up, maintaining and releasing connections. The Management Plane has two functions: Plane management and Layer management. Plane management has no layered structure. It is responsible for co-ordination of all the planes. Layer management is responsible for managing the entities in the layers and performing Operation, Administration, and Maintenance services (OAM).

![B-ISDN Protocol Reference Model](image)

The physical layer consists of two sublayers: the physical medium sublayer and the transmission convergence sublayer. The first sublayer includes physical medium-dependent functions. The second sublayer is responsible for the following functions: transmission frame generation and recovery, transmission frame adaptation, cell delineation, Header Error-Control (HEC) sequence generation and verification, and cell rate decoupling.

The ATM layer is independent of the physical medium. The layer is responsible for the following functions: cell multiplexing and demultiplexing, Virtual Path Identifier (VPI) and Virtual Channel Identifier (VCI) translation, cell header generation and extraction, and generic flow control.

The AAL consists of two sublayers: the segmentation and reassembly sublayer and the convergence sublayer. The first layer is responsible for the segmentation of higher-layer information into a size suitable for the information field of an ATM cell on transmission and the reassembly of the contents of a sequence of ATM cell information fields into higher-layer information on reception. The second layer defines and implements the services that the AAL provides to higher layers.
2.3 UMTS

The Universal Mobile Telecommunication System (UMTS) is a new generation of mobile communications technology expected to be operational around the year 2000. It intends to provide a large community of users with a broad variety of services, including present services provided by GSM (Global System for Mobile communications), DCS 1800 (Digital Communication System in the 1800 MHz band), DECT (Digital European Cordless Telecommunications) and ERMES (European Radio MEssage System). A single system will support end-to-end communication with diverse characteristics and bandwidths, through an infrastructure with fixed and mobile components. UMTS will deliver this communication integrated into a broadband intelligent network exploiting the state of the art principles of B-ISDN, IN and Universal Personal Telecommunications (UPT). UMTS is flexible in access and in the services that it supports, so that it is suited to public, business and private environments.

UMTS offers mobile access to fixed B-ISDN, and operates in a frequency band around 2 GHz. Single-bearer transmission capacity can accommodate up to 2 Mb/s. UMTS integrates different mobile techniques suitable to different environments. Amongst these are cordless, cellular and satellite communications, for areas ranging from home or office to global. A variety of types of radio cells with different sizes and characteristics support UMTS services in dense urban and office situations.

The development of UMTS has been carried out in the project Research and technology developments in Advanced Communications Technologies in Europe (RACE). A similar development is being carried out by ITU-RS TG 8/1 that was called Future Public Land Mobile Telecommunication System (FPLMTS) but is now called International Mobile Telecommunications 2000 (IMT2000).

Within the RACE II project MOBILE NETworks (MONET), research has been performed into the network aspects of the third generation system UMTS. For this study the deliverables and reports of the MONET groups are taken as a starting point.

2.3.1 Relationship to IN and B-ISDN

UMTS is designed as an integrated part of the B-ISDN. Not only will UMTS base stations and B-ISDN fixed terminals be connected to a common network; also the UMTS and B-ISDN services will be integrated. The integration of UMTS and B-ISDN infrastructure will offer cost advantages. It reduces both implementation costs (less hardware to install) and operational costs (less hardware to maintain). Integration of services offers advantages from the user perspective: users should not notice the difference between services offered by either mobile or fixed terminals.

A constraint that exists when integrating B-ISDN and UMTS is that ideally UMTS should have no impact to broadband protocols, or in practice as little as possible. This is partly because B-ISDN is already in a certain state of development, but also because fixed network operators that do not implement UMTS should not be burdened by a possible overhead caused by UMTS.

A way to integrate UMTS into the broadband architecture while causing the least possible modifications to B-ISDN is to apply the IN concepts to implement the
UMTS mobility functions. One of the properties of IN is that, once implemented, it allows introduction of new services without requiring modifications to the existing switching infrastructure. Due to this property IN can play an essential role in integrating UMTS in the B-ISDN, even though IN was originally conceived for flexible service provisioning.

The functional framework of UMTS, depicted in Figure 2-5, adopts these properties. This framework is based on a double scheme for the functional splitting: on one hand, the hierarchical concept is invoked to describe the splitting arising in the access and the core network; on the other hand the IN separation is adopted to distinguish basic infrastructure function, service and control function and data function [MONET 073, Bro93].

![Functional UMTS framework](image)

**Figure 2-5: Functional UMTS framework**

In the Core Network control of mobility procedures and service operation (i.e. the intelligence) are decoupled from the basic transport and switching functionalities performed by Local Exchanges (LEs) and Terminal Exchanges (TXs) to be in line with the IN concept. This way the basic switching infrastructure of the Core Network can be shared. Note that the LEs and TXs are network entities used in B-ISDN. In this sense, the Mobility and Service Control Points (MSCPs) for both local and transit level provide for the required independence from the fixed network and allow maximum flexibility in the provision of mobility on fixed networks. The Mobility and Service Data Points (MSDPs) provide the flexibility for the management of the data involved in the service provision and the control of the communications in the distributed database. Note that the MSCP and MSDP are network entities, having a similar role as the IN entities SCP and SDP.

All the radio related functions need to be available in entities of the Access Network. At the basic switching infrastructure level, two hierarchical levels are required: one dedicated to provide the radio interface with the Mobile Terminal (MT), the BTS; and a second one dedicated to provide concentration, switching and transcoding capabilities required in the Access Network for a proper interworking with the Core Network, Cell Site Switch (CSS) in the MONET terminology.

The mobility control and service operation functionalities required in the Access Network are allocated to the MSCP associated to the CSS, (in principle) separated from the basic switching and transport functionalities in accordance with the basic IN concepts. In the same way, the data functionalities are allocated to the MSDP.
2.3.2 Environments

Within the MONET project different environments have been identified that need to be supported by UMTS (to enable flexibility in access and supported services). These identified environments are [MONET 071, MONET 073]:

- **Public highway (PHW):**
  This environment can be modelled by assuming two directions of traffic, remaining on the straight highway, with variable speed and density.

- **Public low traffic (PLT):**
  In this environment the sparsely distributes MTs have very distinct mobility levels (i.e. high or low speed cars, non mobile users, etc.) and follow random directions.

- **Public metropolitan high traffic (PHT):**
  Low speed mobiles (cars and buses) and pedestrians moving in random directions within the cellular coverage that is determined by the urban physical setting.

- **Business CPN (BCPN):**
  By Business Customer Premises Network (BCPN) environment, it is considered administration places and offices, usually placed in buildings of urban areas or in large companies sites where the UMTS users are not moving or randomly roaming at a very low speed.

- **Domestic CPN (DCPN):**
  Two basic situations are foreseen: the first refers to DCPNs located in city centres or surroundings with residential skyscrapers. In this case, only inside building coverage is acceptable and high density of users is likely. The other situation is represented by very disperse residential areas where users' concentration is much lower. An external coverage of the areas surrounding the house is necessary for service reasons.

- **Mobile CPN (MCPN):**
  The concept of Mobile premises (MCPN) is based on the possibility of supplying the users travelling on a public or private means of transport with a local (mobile) radio coverage.

2.3.3 UMTS Reference Configuration

A possible reference configuration for UMTS integrated into B-ISDN is shown in Figure 2-6 for User and Control Plane communications [MONET 100].

In the User Plane the MT would communicate with the BTS in the RAS via the UMTS radio interface. ATDMA and CODIT projects have been esteemed as examples of possible UMTS radio interfaces to consider transport and transport interworking. The RAS may contain a CSS for routing traffic between the fixed network or customer network and appropriate BTS. The RAS for each group of radio cells and BTSs would be connected either to a private switch via the private User Network Interface (UNI) or Sb or directly to the B-ISDN fixed network via the public UNI or Tb. Fixed B-ISDN terminals may also be connected to the same customer network or LE. Note that some of the entities may be omitted for certain environments. The resulting reference configurations are discussed in chapter 4.

Switching elements in UMTS (CSS, private switch, LE and TX) are assumed to be based on B-ISDN using ATM for the transport of user and signalling information. Additional physical entities for transport interworking, handover and macro diversity may be added to this reference configuration, or such functions may be
Development of a generic model for handover in UMTS

The development of a generic model for handover in UMTS is included within the physical entities shown in Figure 2-6. The allocation of (additional) functions for handover and macrodiversity is discussed in chapter 5.

![Figure 2-6: UMTS User and Control plane Reference Configuration](image)

IN additional signalling messages must be transported between IN elements consisting of MSCP and MSDP. These elements may be connected to CSS, private switch, LE or LE. Some of the MSDP and MSCP entities may be omitted for certain environments in which case MSCPs deeper in the network must be used instead.

### 2.3.4 Radio Interfaces

UMTS is supposed to be flexible enough to support different innovative radio access schemes and the second generation systems. In the area of the innovative types of radio access, this study considers the results from the RACE II Projects R2084 ATDMA - Advanced TDMA Mobile Access' and R2020 CODIT - Code Division Testbed'. The debate about the use of these two types of radio multiple access is still continuing in both European (ETSI) and world wide (ITU) standardisation bodies. In the area of the second generation types of radio access, this study considers the standards developed for the GSM (Global System for Mobile communication) and DECT (Digital European Cordless Telecommunication) systems.

#### 2.3.4.1 ATDMA

The RACE R2084 ATDMA project developed adaptations of traditional TDMA (Time Division Multiple Access) and new techniques to the system capability of TDMA for current and future systems. The ATDMA system concept supports advanced control techniques for a flexible TDMA transport system where the air interface's burst and frame structures, modulation and error correction scheme are adapted to match the current needs of the system.

Although a formal reference configuration has not been adopted inside the ATDMA project, a suitable logical model can be derived from the ATDMA Protocol Model which consists of simply the three logical entities Mobile Station (MS), Base Station (BS) and 'Network' [MPLA 7].
Rather than a physical model, the elements in the ATDMA model represent all functions which are logically associated with a single MS or BS or with the rest of the entire UMTS network. In practice the BS function will be distributed between equipment that is physically located at cell site and other network entities.

### 2.3.4.2 CODIT

The air interface concept for the CODIT testbed has been focused on the flexibility requirements of a third generation system, both to operational demands and demands from a wide set of services. DS-CDMA (Direct-Sequence Code Division Multiple Access) was chosen as access method since it could in the most efficient way provide this flexibility. Features like variable and mixed data-rates have been incorporated in the system concept, specified and implemented in the CODIT testbed.

The CODIT Reference Configuration, depicted in Figure 2-8, is derived from the CODIT Network Reference Model [MPLA 007]. This configuration includes four functional groups: Mobile Station (MS), Base Station (BS), Radio Network Controller (RNC) and Mobile Control Node (MCN).

The RNC manages the macrodiversity functionality: the frame combiner or selector (combining the frames coming from the different BSs connected to the same MS, or simply selecting the best frame) is located within the RNC. In this case, the RNC identifies a macro group (i.e. the whole set of BSs that could be involved in a communication with the same MS).

The previous paragraph applies to the classical definition of macrodiversity, but in a Code Division Multiple Access (CDMA) system also adjacent groups can use the same portion of the frequency band (a continuous coverage layer could use a single portion of the frequency band). To support this higher layer macrodiversity functionalities are provided by the MCN. Selective repeat combining is used which chooses the best frame or block coming from the RNCs. The MNC can mainly be seen as the switching centre that allows the interconnection of the UMTS network to the fixed network (e.g., B-ISDN). Then the related InterWorking Units (IWUs) are located in this functional group.

### 2.3.4.3 GSM

GSM is a digital cellular communications system which has rapidly gained acceptance and market share world-wide, although it was initially developed in a
European context. In addition to digital transmission, GSM incorporates many advanced services and features, including ISDN compatibility and world-wide roaming in other GSM networks. A unique feature of GSM, not found in older analog systems is the Short Message Service (SMS). This is a bidirectional service for short alphanumeric (up to 160 bytes) messages. GSM represents a complete stand-alone system, with fully specified radio and network interfaces, that interworks with fixed networks.

The GSM Reference Configuration identifies three parts: the Mobile Station (MS), the Base Station Subsystem (BSS), and the Network Subsystem (NS).

The BSS controls the radio link with the MS. The BSS is composed of two parts, the Base Transceiver Station (BTS) and the Base Station Controller (BSC). These communicate across the standardised Abis interface, allowing operation between components made by different suppliers. The BTS consists of transceivers that define a cell and handles the radio-link protocols with the MS. The BSC manages the radio resources for one or more BTSs. It handles radio channel setup, frequency hopping, and handovers.

The NS performs the switching of calls between the mobile and other fixed or mobile network users, as well as network management. The central component of the NS is the Mobile Switching Centre (MSC). It acts like a normal switching node of the PSTN or ISDN, and additionally provides all the functionality needed to handle a mobile subscriber, such as registration, authentication, location updating, handover, call routing to a roaming subscriber.

2.3.4.4 DECT

DECT is a short range pico cellular digital radio access system that allows a single handset to access several types of systems (residential, business, public) and services (quality voice, ISDN, high data rate). It supports full European roaming. As an access technology via a radio interface, DECT makes the specific services and features of the network it is attached to, transparently available to the users of DECT handsets. For this reason, only the (lower layers of the) radio interface is completely specified. The other interfaces (and the upper layers of the radio interface) are left open to the peculiar application required, e.g. public, wireless PABX.

A DECT system may be connected to two types of networks. Firstly, DECT can be connected to a local network, offering telecommunications services which are rich in features or performance; examples are PABXs or high speed LANs. Secondly, DECT can be connected to a global network, offering limited services and rigidly imposing the constraints of such networks; examples are the PSTN and the PSPDN.
In general, a DECT Access Network (DAN) consists of the following two Functional Groups (FGs): Portable Termination (PT) and Fixed Termination (FT). This is depicted in Figure 2-10. The PT functionality is implemented with one Physical Entity (PE), the DECT HandPortable (DHP). The FT functionality can be implemented with one or two PEs, the DECT Radio Site (DRS) and optionally the DECT Site Controller (DSC).

### 2.3.5 Bearer Types

UMTS supports different bearer types. A distinction has to be made between the bearer types supported in the B-ISDN Core Network and the bearer types supported over the radio interface. Due to radio limitations, data transport on the radio interface can be different from what is used on interfaces in the fixed network. Transport interworking is used to overcome these differences in transport [MPLA 007, RAINBOW 1].

**Constant Bit Rate (CBR)**

CBR is targeted for loss and delay sensitive services with deterministic and constant cell rate. A constant cell rate in the CBR context is defined as single cells equally spaced in time and with the same filling level in case partially filled cells are used. The main usage of CBR services is for emulating or interworking with existing circuit switched services.

**Variable bitrate (VBR)**

The VBR service category is intended for the use by services that have a statistically predictable but variable bit rate requirement and cannot adjust their bit rate for variations in network loading.

**Speech**

This bearer type is targeted for asynchronous and delay sensitive services.

**Unconstrained delay**

The main aspect of this bearer type is that delay is not important, i.e. high delays and delay variations can be tolerated. Furthermore, there is no synchronisation requirement between source and destination. On the other hand, the requirements on error rates are high.
2.4 Rainbow

The project Radio Access INdependent Broadband Over Wireless (RAINBOW) is a project within the European research framework ACTS. The RAINBOW project will develop a network architecture for the RAS of UMTS. This architecture should be independent of the radio interfaces used. The feasibility of this architecture is studied through a test-bed implementation of the RAS. The main goals of the project are:

- To demonstrate the feasibility of a generic UMTS access infrastructure that can support both innovative radio interfaces (ATDMA and CODIT) and existing radio interfaces (GSM and DECT);
- To develop solutions for the migration of second generation mobile systems towards UMTS.
- To determine the boundary between radio dependent and radio independent parts of the UMTS infrastructure;
- To develop solutions for the integration of the UMTS access infrastructure and the B-ISDN fixed network
- To contribute to the standardisation effort on UMTS.

The study that is reported in this document is closely related to the developments within the RAINBOW project.
This chapter describes the handover process in UMTS. The first section (section 3.1) introduces the reader to the concept of handover as well as the causes that require a handover. In section 3.2, the aspects on which the handover process depends are identified and discussed. The chapter concludes with a description of the MONET handover Functional Model (section 3.3).

3.1 General description

An important issue within UMTS is handover. Handover is a feature, resulting in a change of physical channels, radio channels or terrestrial channels, involved in an association between a mobile terminal and the fixed network while maintaining this association. Four causes exist that require this change. A handover may be required as caused by [MONET 99]:

- crossing a cell boundary by an active mobile terminal;
- deterioration of the quality of the active radio link;
- user service profile issues, e.g. a user wants to switch from the public network to a private network;
- network management issues, e.g. redistribution of traffic for Operations and Maintenance reasons.

An example of a handover caused by the crossing of a cell boundary is depicted in Figure 3-1.

Consider a mobile UMTS subscriber who is moving from Base Transceiver Station 1 (BTS1) towards BTS2. The radio link between the Mobile Terminal (MT) and BTS1 will deteriorate, due to the increasing distance between them. To prevent loss of the call when the subscriber crosses the cell boundary between BTS1 and
BTS2, the radio channel between the MT and BTS1 has to be exchanged with a radio channel between the MT and BTS2; the radio connection has to be handed over, from BTS1 to BTS2. Note that this example describes the inter BTS handover case (section 3.2.5).

The association between the MT and the BTS is referred to as (radio) link. The association between the MT and the receiving party is referred to as path. The path from the MT to the LE is referred to as the uplink path. The path from the LE to the MT is referred to as the downlink path. The process of initiating the handover function, exchanging the old path through the network with a new path through the network, and releasing the old path is referred to as the handover process.

3.2 Handover aspects

The common features of the different handover scenarios have been analysed. This analysis pointed out that the handover process in UMTS depends on several aspects. These aspects are:

- Handover initiation points: single handover initiation point or two handover initiation points;
- Handover initiation procedures: mobile initiated, mobile originated, network initiated, network originated or special handover requests;
- Bearer type: Speech, Constant Bit Rate (CBR), Variable Bit Rate (VBR) or unconstrained delay;
- UMTS reference configurations and environments: public, business, or domestic with or without CSS or MSCP (Access) level;
- Handover cases: intra BTS handover, inter BTS handover, inter CSS handover, inter LE handover, or inter environment handover;
- Handover types: forward or backward handover, hard handover with a make-before-break or a break-before-make scenario, and soft handover with or without the use of macrodiversity with hard or soft combining;
- Radio interface: ATDMA, CODIT, GSM or DECT.

Each handover aspect identifies the options that are possible in the particular part of the handover process, during which the aspect is relevant. Because of this, each handover scenario can be described by a combination of options of these handover aspects.

The following paragraphs will describe these aspects, the options regarding a particular aspect, and the impact of the aspects regarding the handover process.

3.2.1 Handover Initiation points

The handover initiation points define the Network Entities (NEs) where the information needed for the handover process is gathered and where the need for a handover is determined.

MONET distinguished two groups of handover with respect to the handover initiation points. In the first group there is a single handover initiation point. The decision to start the handover is taken either in the MT or in the network. In the second group there are two possible initiation points. Both the MT and the network can initiate a handover procedure.
3.2.2 Handover Initiation procedures

The handover initiation procedures define the way the handover process has been initiated. In the case of a single initiation point, three handover procedures can be distinguished:

- **Mobile initiated handover**: only the mobile terminal monitors the quality of the radio link and decides whether to initiate an handover;
- **Network initiated handover**: only the network monitors the quality of the radio link and decides whether to initiate an handover.
- **Mobile assisted handover**: the mobile terminal sends its information about the quality of the radio links to the network. The network also monitors the quality of the current radio link. The decision to start a handover is taken by the network.

In the case of two handover initiation points, two procedures are possible:

- **Mobile originated handover**: Both the MT and the network monitor the quality of the radio link. The decision to start a handover is taken by the MT.
- **Network originated handover**: Both the MT and the network monitor the quality of the radio link. The decision to start a handover is taken by the network.

In stead of these requests the MT and the network can force a handover. When a UMTS subscriber leaves the public environment and enters a business environment, he or she can request a handover from the public environment to the business environment (for billing reasons). The network can force a handover due to network management reasons, e.g. redistribution of traffic for operations and maintenance reasons. These requests are referred to as special handover requests.

3.2.3 Bearer types

The bearer types define the constraints regarding signal quality requirements, synchronisation requirements, and delay requirements.

When discussing bearer types, that are to be provided, a distinction must be made between the bearer types supported in the B-ISDN Core Network and the bearer types supported over the radio interface. Due to radio limitations, data transport on the radio interface can be different from what is used on interfaces in the fixed network.

For example, to efficiently use the radio resources, the data transport on the radio interface can be encoded. Transport interworking is used to overcome these differences in transport [MPLA 7]. Transport interworking is no subject of study in this report.

The identified bearer types are:

- **Speech**: One of the most important services in mobile systems will be the telephony (speech) service. The speech bearer type requires low delays, synchronous service, and transcoding (source encoding) functions for efficient use of radio resources. It tolerates moderate Bit Error Rates (BERs).
- **Constant Bit Rate (CBR)**: This service is rather similar to the telephony service. The CBR bearer type has the low delay and synchronisation requirement in common with the bearer type belonging to the telephony service. However, there are also some differences. For example, the expected
BER for this bearer type is a number of magnitudes smaller than for speech (10^-6 instead of 10^-3).

- **Variable Bit Rate (VBR):** This bearer type is intended for the use by services that have a statistically predictable but variable bit rate requirement and cannot (or do not want to) adjust their bitrate for variations in network loading.

- **Unconstrained delay:** The TCP/IP connection can be taken as an example of such a bearer type. The delay aspect of this bearer type is not important, i.e. high delays and delay variations (delay jitters) can be tolerated. Furthermore, there is no synchronisation requirement between source and destination. Because of the low BER requirement and the delay tolerance, retransmission protocols (Automatic Repeat reQuest (ARQ)) can be used in the access network to increase the performance (reduce the error rate) of the service.

The constraints regarding the requirements of the bearer types (signal quality requirements, synchronisation requirements, and delay requirements) are used to determine how the handover can or must be performed.

### 3.2.4 UMTS reference configurations and environments

The UMTS reference configurations and environments define the way the handover functionality has been allocated to the Functional Groups (FGs) of the UMTS network. Furthermore they define the physical characteristics of the Radio Access System (RAS) like the cell size and cell layout.

The Functional Groups (FGs) foreseen in the reference configurations are MT, BTS, CSS, MSCP (access), MSDP (access), LE, TX, MSCP (core), and MSDP (core). The Functional Groups do not yet imply a specific set of functions. They serve as nodes where functionality can be allocated. Likewise, the interfaces between Functional Groups are physical interfaces that can be implemented using different protocol stacks (Transport) or can support different Functional Interfaces (Control).

In the public environment three reference configurations can be used depending on the network operator preferences. In the first configuration (Figure 3-2), the BTSs are directly interconnected to the LE. This configuration is considered for public low traffic and public metropolitan high traffic.

![Figure 3-2: Reference configuration without CSS level](image)

In the second option (Figure 3-3), the BTSs are connected to a CSS providing concentration and local switching for handover. Mobility control is still located in the core network.
The third configuration (Figure 3-4) is the same as the second one, except that the local mobility control is now handled in the MSCP of the RAS.

The RAS in the business environment is implemented as a privately owned Customer Premises Network. The CSS will in this case be a B-ISDN PBX that also connects fixed terminals. Possibly BTSs and fixed terminals are connected to the CSS using the same interface (i.e. a common bus system). In the business environment two reference configurations are identified. In the first case (Figure 3-5) the Customer Premises Network (CPN) provides internal location management. In the second case (Figure 3-3), the location management is performed by the public network only.

The RAS in the domestic environment is implemented as a privately owned CPN. In this environment two reference configurations are identified. In the most simple configuration (Figure 3-2), the BTS is connected to the ordinary subscriber line for fixed communications. In the second case (Figure 3-3), the CSS is implemented as a basic B-ISDN PBX, connecting both fixed terminals and BTSs.

The reference configurations [RAINBOW 4] are valid for either the public, business or domestic environment. Another two reference configurations for the
Development of a generic model for handover in UMTS

mobile CPN environment can be found in [MONET 73]. A given reference configuration is used depending on the environment and on the network operator preferences.

Figures 3-3 to 3-6 suggest a tree structure for the interconnections between the LE, CSS and BTS. However, interconnections of CSSs are also possible and one BTS can be connected to different CSSs. These alternatives can be used to limit the impact of mobility on the core network, as with these interconnections the handovers can be handled below the LE level.

The logical interconnections between RAS network elements can be supported by various physical interconnection topologies, such as a star, a ring, or other topologies (e.g. chain, bus topology). A tree is efficient regarding use of cables. Star configurations allow shorter links to be used than with a tree structure. A ring structure offers inherent redundancy. The choice of a given interconnection topology depends on parameters as cost of ownership (equipment cost, operational cost), fault tolerance characteristics, performance aspects, etc.. The study, described in this report, has made use of a tree topology without interconnections between network elements.

3.2.5 Handover cases

The handover cases define which Network Entities (NEs) are involved during a handover. Depending on the UMTS environment, several handover cases are identified.

When the quality of the active radio link is deteriorating, while the UMTS subscriber remains in the range of a BTS, a handover is needed to prevent loss of the association. In this case the BTS will measure the quality of candidate radio links. If a radio link with a higher quality is detected, the BTS will execute a handover to this new radio link. This handover case is referred to as intra BTS handover. Figure 3-6a depicts this handover case.

The old connections are shown as dashed lines and the connections after the handover are shown as continuous lines. The connections that remain unchanged are shown as dotted lines.

Figure 3-6: Handover cases

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Suppose a UMTS subscriber is roaming out of the range of one BTS into the range of another. In this case, the first BTS needs to perform a handover to the new BTS, in order to remain the association. When these BTSs are attached to the same CSS, this type of handover is referred to as **inter BTS handover**. This handover case is depicted in Figure 3-6b.

If these BTSs are attached to two different CSSs and these CSSs are attached to the same LE this type of handover is referred to as **inter CSS handover**. This handover case is depicted in Figure 3-6c.

If the CSSs are attached to two different LEs, this handover case is referred to as **inter LE handover**. This handover case is depicted in Figure 3-1d. This last handover case has not been taken into consideration in this study.

The **inter environment handover** refers to the case that, e.g. a user roams from the highway environment into the public environment. This handover case has not been taken into consideration either.

Note that the network configurations that are shown in the figure are examples of possible UMTS network configurations. UMTS network configurations depend on the environment in which the network is active, and can be different from the one that is shown. This is dealt with in the previous section of this chapter.

### 3.2.6 Handover types

The handover types define transport and control aspects of the handover process.

The handover types concerning transport aspects define how the actual switching of the connections from the old path to the new path is done. In this context the old path is the path before the handover. The new path is the path that has been established during the handover process. This switching takes place in both the network (at the network switching point) and the MT. The handover types concerning control aspects define how the control information needed for the handover process is passed through the network.

**Transport aspects**

During a handover, the transport in the RAS should provide the required Quality of Service (QoS). This means that the target values assigned to the end-to-end performance parameters (delay, variation in delay, loss rate, throughput) are kept within the limits specified at call-setup. These limits are related to the actual service being considered; handover needs to support a range of delay critical (e.g., telephony service) and loss critical (e.g., unconstrained delay data) services.

In this framework, two basic types of handover have been identified: **hard** and **soft handover** [MONET 100, RAINBOW 1]. Hard handover refers to the situation that connections are just switched over from one path to another without taking care that data will not be lost on the old path. Soft handover refers to the situation when connections through the new path are established before the old path is released.

In [RAINFOX 001] a further distinction has been made of the hard handover type. Two scenarios of hard handover are identified: **make before break** and **break before make**. In a make-before-break scenario the assumption is made that there is sufficient time for the establishment of the new path. After this establishment and the switching to this new path, the old path can be released. In a break-before-make scenario, the radio link between the MT and the old BTS is released.
before the establishment of the fixed network connection between the new BTS and the network switching point. This scenario could be used in environments where sudden and abrupt attenuation can occur on the radio links.

Control aspects
The physical environment characteristics pose time limitations to perform handover. The timing constraints enforce the use of certain handover types to efficiently support mobility within the RAS. To this end, two different candidate handover types, differing in terms of control functionality, have been introduced: forward and backward handover [MONET 100, RAINBOW 1].

Forward handover sends all information needed for the handover process directly through the new path via the new BTS. Backward handover passes all information needed for the handover process through the old path via the old BTS. The selection between these handover types depends on the physical characteristics of the environment that the MT moves within. For example, in a pico-cellular environment, forward handover appears more appropriate to use, since the time limitations for handover execution are strict. On the other hand, if an MT moves from a macrocell to another macrocell, a backward handover should be used.

Macrodiversity
In order to ensure the appropriate transmission quality, which in turn guarantees service quality to the UMTS subscribers, it is often required to use macrodiversity. Macrodiversity transports the same information along a number of parallel paths between the MT and the fixed network. The common points in the MT and network must combine the information received from all these paths and select the information to be forwarded using suitable combining algorithms [MONET 107, SIG2 007].

The macrodiversity concept (especially hard combining) is strongly related to the support of soft handover for moving MTs.

Seamless handover
In principle, the service quality at the user service level should not be degraded by the handover process [MONET 100, RAINBOW 1]. The most ideal situation is that the handover process is unnoticeable for the subscribers. This handover process is referred to as seamless handover. For a seamless handover, the transport aspects of the handover must fall within the specified ATM transfer QoS contract for the connection. Seamless handover is not considered as a separate type. Depending on the application and the QoS agreements both soft and hard handover can be seamless or not.

3.2.7 Radio interfaces
UMTS is supposed to be flexible enough to support different innovative radio access schemes (ATDMA, CODIT) and the second generation systems (GSM, DECT).

The debate about the use of the innovative radio access schemes is still continuing in European (ETSI) and world wide (ITU) standardisation bodies. Therefore, this study assumes that all functionality with respect to handover is supported by these innovative systems.
Attaching second generation systems to a new UMTS network is an attractive option in migration as it fulfils one of the key requirements of network operators: the re-use of existing infrastructure. When discussing the re-use of existing infrastructure, the base stations are of prime importance. It is the base stations, rather than network entities such as exchanges and mobility management entities, that constitute the major part of the investments in a mobile network. Therefore a migration scenario that focuses on the re-use of base stations rather than a re-use of the network infrastructure would seem to be an attractive premise, in the context.

Two cases can be considered for re-using second generation base stations:

1. Base stations connected to a UMTS network:

   In this case the complete second generation base station and the complete second generation protocol stack are re-used. Because no changes are made to the radio interface, the subscribers can use their existing terminals. However, connecting these base stations to the UMTS network could enable these existing subscribers to use some new or enhanced services provided by the UMTS mobility and service control.

2. An extension of the second generation radio interface that uses the existing lower layers:

   In this case only the lower layers of the radio interfaces are used. Existing terminals cannot be re-used. However, new services including enhancements to transport capabilities and with UMTS mobility and service control can be provided. It still allows the re-use of existing base station sites, transceiver equipment, and frequency licence. This option is already exploited in GSM Phase 2+ for the General Packet Radio Service (GPRS) and High Speed Circuit Switched Data (HSCSD) services.

Even within the base station architecture, the investments in the actual base station equipment may not be the most important aspect to consider. More important may be to re-use the same base station site. If not the investments in buildings, masts, and antennas, then certainly the planning of sites and acquiring the permission for building sites is the most important hurdle to take when building a network for mobile communication. Therefore, even scenarios where a significant part of the base station equipments is replaced may still be attractive if they allow the re-use of sites and antennas.

Re-using the existing frequency licence is another aspect to consider. As a frequency licence is an important asset for a mobile operator, it may be attractive to provide new services in the same frequency band. In this case only the very basic features of the radio interface are re-used, i.e. only the very lower layers of the protocol stack.

In this study it is assumed that only the lower layers of the protocol stack of the second generation radio interfaces are re-used.
3.3 Functional Model

The Handover Functional Model, as illustrated in Figure 3-7, identifies all the Functional Entities (FES) involved in the Handover process [MONET 099]. The FEs have been given special names corresponding to the kind of functions they perform. The lines between the FEs show the allowed relationships between the FEs. FEs that have a relationship can exchange information by Information Flows (IFs). A description of the IFs (names of the messages as well as the contents of the messages) is given in [MONET 99] and will not be repeated here.

The Handover Functional Model identifies three phases: the Information Gathering Phase, the Decision Phase and the Execution Phase. These phases will be discussed in the following paragraphs.

### 3.3.1 Information Gathering Phase

The HI entity has to be provided with information, to be able to identify the need for a handover. During the Information Gathering Phase this information is obtained and forwarded to the HI entity. Several FEs are responsible for this task.

The MEF entity gathers measurements concerning a specific active link. These measurements are forwarded to the HI entity in a defined form on a regular short-term base.

The TCCU entity performs measurements to provide the HI entity with a list of candidate cells for a specific user. It also provides the HI entity with related information, e.g. radio link quality parameters.

The HUPU entity contains a subset of the subscriber profile, specifically all the subscriber-related information that is relevant to the handover process (bandwidth requirements, QoS requirements, access rights, priorities, environment selection, etc.).

The SHRU entity issues handover requests forced by the UMTS user.

The HCA entity sets and updates the Handover Criteria (HC), according to the instructions it receives from the resources control and the network management.
The last entity that has been identified in this phase is the HC entity. It represents the Handover Criteria used in the handover procedure. The HC entity supplies the HI entity with all the quasi-static parameters needed. The network can use these entities to influence the initiation of the handover process.

### 3.3.2 Decision Phase

In the previous phase, information has been gathered and forwarded to the HI entity. In the Decision Phase, the HI entity processes this information and, if necessary, issues a handover request to the HD entity. Along with this command, it supplies the HD with all the available information needed for the identification of the handover control point, the type of the identified handover (hard handover or an add/drop connection in a macrodiversity context) and the handover completion constraints.

If the HI entity receives a forced handover instruction from the SHRU, it interacts with the HUPU to check the compatibility of a forced handover, requested by the user, with the user profile. After the handover execution, it reports the result of a forced handover request to the SHRU.

As described earlier, the HD entity receives a handover execution request from the HI entity. The HD entity determines the location of the handover control point. It negotiates about a possible service degradation by using information from the TCCN entity and HUPN entity.

The TCCN entity provides the HD entity with information about the availability of a number of fixed resources in order to be able to negotiate about a possible service degradation. Furthermore it provides the HD entity with radio resource management information.

The HUPN entity contains a subset of the subscriber and the service profile.

The HD entity takes the final decision about effecting the handover request using all relevant information, which includes radio resource management information and service quality negotiation result. It also receives and processes a forced handover request from the network (issued by the SHRN entity).

If no problems have been encountered, the HD entity instructs the HOC entity to execute a handover. It provides information concerning the position of the new connection point, if this has not previously been identified in the HI entity. Furthermore, it provides handover completion time constraints to the HOC entity.

Finally, the result (handover completion) is reported to the HI entity.

### 3.3.3 Execution Phase

The Execution Phase of the handover procedure starts with the reception of handover execution instructions at the HOC entity. This FE also receives information required for the handover execution. It keeps track of the co-ordination of the handover process. Therefore, it instructs and receives reports of the results of a number of FEAs.

The BC (and RBC) entity receives instructions to establish or release bearers from the HOC entity. It establishes bearers with defined bandwidth or releases bearers.

The SBC entity takes care of the establishment and release of a bridge between a number of bearers, switching from one bearer to another.
The CMC entity controls the combining and multicasting functions in a macrodiversity group. It controls the set-up, release and change of combine and multicasting function.

The HSE entity takes care of the transfer of the old encryption key to the new encryption handler.

The CPT entity is responsible for the transfer of a control point. This might be needed when an inter LE handover has occurred, or a handover between two different environments.

The RRT entity initiates a rerouting procedure from the HOC entity. The path through the network needs rerouting, when a handover procedure has made use of the interconnection of two identical FGs. An example of this is a handover from one BTS to another through two interconnected CSSs. In this case both the uplink and the downlink path from the LE through the old CSS to the new CSS must be replaced by a direct path. In this case the direct path is the path (both uplink and downlink) from the LE directly through the new CSS.

3.4 Conclusions

In this chapter the handover process has been described. The concept of handover has been clarified and the causes that require a handover have been described.

The common features of the different handover scenarios have been analysed. This analysis pointed out that the handover process in UMTS depends on several aspects. Each handover aspect identifies the options that are possible in the particular part of the handover process, during which the aspects is relevant. Because of this, each handover scenario can be described by a combination of options of these handover aspects.

The chapter has concluded by presenting the MONET handover Functional Model. This model identifies three phases in which the handover process can be divided. Furthermore, it structures the required functionality for handover into Functional Entities.
The previous chapter identified all aspects of the handover process and presented the Handover Functional Model. This model has been taken as a starting point in the development of the Handover Generic Model. The Handover Generic Model is a model of the handover functionality that handles all the handover scenarios, demanded by the handover aspects. This chapter describes this model. Accordingly, the impact of the handover aspects on the handover application protocol (section 4.2) and the essential relationships between the handover aspects and the identified phases of the handover process have been described (section 4.3). The chapter concludes with the resulting Handover Generic Model (section 4.4).

4.1 Introduction

The handover process in UMTS depends on several aspects, as described in chapter three. The handover initiation points define the Network Entities (NEs) where the information needed for the handover process is gathered and where the need for a handover has been determined. The handover initiation procedures define the way the handover process is initiated. The bearer types define the constraints regarding signal quality requirements, synchronisation requirements, and delay requirements. The UMTS reference configurations and environments define the way the handover functionality has been allocated to the Functional Groups (FGs) of the UMTS network. Furthermore they define the physical characteristics of the Radio Access System (RAS) like the cell size and cell layout. The handover cases define which Network Entities (NEs) are involved during a handover. The handover types define transport and control aspects of the handover process (i.e., the way the actual switching between bearers will be performed). The handover functionality depends on the radio interface that the access network of UMTS has been equipped. Finally, the radio interfaces define which radio techniques (i.e., lower layer protocols) will be used on the air interface.

These handover aspects demand different scenario's to perform a handover. In order to perform a handover efficiently, all these aspects have to be taken into account in the development of the handover application protocol. For this reason, a Handover Generic Model has been developed that is suitable for all handover scenario's.

This chapter describes this Generic Model. Section 4.2 describes the impact of the handover aspects on the application protocol. In section 4.3 the handover aspects will be related to the handover phases, according to the handover Functional Model. Finally, section 4.4 describes the handover Generic Model.

4.2 Impact of handover aspects

The feasibility of the Handover Generic Model will be verified by formulating specifications of a minimum number of processes. These processes communicate at application level (see chapter 6). This entails that only the handover aspects
that require signalling at application level can be taken into account, concerning the Handover Generic Model.

For this reason, the impact of the handover aspects on the application protocol is studied and described. This impact can be categorised as follows, ordered by decreasing impact:

1. Impact on what protocol messages are sent and in which order: e.g. a Mobile Originated handover requires communication between Handover Initiation (HI) entities;
2. Impact on the allocation of FE: e.g. the handover cases require a Bearer Control (BC) entity at each network node;
3. Indirect impact: e.g. the bearer types impact the appropriate parameter settings in the parameters.
4. No impact: e.g., the used radio interface does not impact the application protocol (only the lower layers).

Figure 4-1 depicts the distribution of the handover aspects on the four categories:

![Figure 4-1: Impact of handover aspects on the application protocol](image)

**Category 1.**

**Handover initiation points:**
In the case of two handover initiation points, the originating HI entity will notify the other HI entity that the need for a handover has been detected. At the end of the handover process, the originating HI will notify the other HI whether the handover has been performed successfully.

**Handover initiation procedures:**
A Special Handover Request from the User requires different protocol messages in comparison to, e.g. a mobile initiated handover.

**Handover types:**
A soft handover requires other protocol messages than a (seamless) hard handover.
The protocols needed between FEs are described in chapter 6.

**Category 2.**

*Handover cases:*
An intra BTS handover involves the Radio Bearer Control (RBC) entities at MT and BTS level. An inter BTS handover also involves a BC entity at CSS level.

*UMTS environments and Reference Configurations (RCs):*
Figures 3.3-3.6 indicate that this handover aspect affects the allocation of the FEs.

The allocation of the FEs are described in chapter 5.

**Category 3.**

*Bearer Types:*
The bearer types result in different timing constraints for the execution of the handover process. This is handled by the setting of an appropriate priority parameter in messages to certain FEs. The handover type that will be executed depends on the timing constraints that result from the bearer types. Hence, the bearer types are closely related to the handover types.

**Category 4.**

*Radio interfaces:*
The radio interfaces do not impact the application protocol (only the lower layers).

As described earlier, the Handover Generic Model will be verified at application level. Therefore, this Model will not cover the handover aspects that have no impact on the application protocol. Consequently, the radio interfaces will not be covered by the Handover Generic Model.

### 4.3 Handover aspects versus handover phases

This section describes which handover aspects are relevant during each phase of the handover process. Figure 3-7 depicts the handover Functional Model. This model identifies three phases, the Information Gathering Phase, the Decision Phase, and the Execution Phase.

During the Information Gathering Phase, information is gathered and forwarded to the HI entity. Hence, the handover aspects handover initiation points and handover initiation procedures are relevant during this phase.

This information will be processed during the Decision Phase. If the need for a handover has been detected, calculations will be done to decide how the handover should be executed. The handover aspect that is relevant during this calculation is the bearer type.

During the Execution Phase the actual handover will take place. This requires setting up, switching between, and release of bearers. Hence, the handover cases and handover types are relevant during the handover Execution Phase.

The relationship between the handover aspects and the phases of the handover process have been depicted in Figure 4-2. The arrow indicates that the handover process starts at the top of the figure and is completed at the bottom of the figure.
4.4 The handover Generic Model

This model has been divided into three phases, according to the Handover Functional Model: the information gathering phase, the decision phase and the execution phase.

4.4.1 Information gathering phase

During this phase information is gathered that is required by the handover process. The handover aspects that are relevant in this phase are the handover initiation points and the handover initiation procedures. For this reason the information gathering phase has been divided into two parts: the handover initiation points part and the handover initiation procedures part.

Depending on the handover initiation points, the information is gathered in the Mobile Terminal (MT), in the network or in both. Generally, there are three options with respect to the handover initiation point, being the place where the information is gathered. The first option refers to the situation that the information is gathered in the MT. The second option refers to the situation that the information is gathered in the network. Both options are very similar and are referred to as the single handover initiation point configuration. The third option refers to the situation that the information is gathered in both the MT and the network. This option is referred to as the two handover initiation points configuration.

With respect to the handover initiation points, nine options have been distinguished. Five are relevant in the case of a single handover initiation point and four are relevant in the case of two handover initiation points.

Single handover initiation point

In the case the information is gathered in the MT, the handover process can be Mobile Initiated (MI). In the case the information is gathered in the network, the handover process can be Network Initiated (NI) or Mobile Assisted (MA). The last procedure is only possible when the MT sends its information about the quality of the radio links to the network.
In both cases the handover process can be forced by the user, the Special Handover Request from the User (SHRU), and by the network, the Special Handover Request from the Network (SHRN).

**Two handover initiation points**

In this case the information relevant to the handover process is gathered in both the MT and the network. If the need for handover has been detected in the MT, the handover initiation procedure is referred to as Mobile Originated (MO) handover. If the need for handover has been detected in the network, the handover initiation procedure is referred to as Network Originated (NO) handover.

If the handover process has been forced by the user or the network, the handover initiation procedure is referred to as SHRU and SHRN respectively.

### 4.4.2 Decision phase

During this phase the information gathered in the previous phase is processed and if necessary a handover request will be issued. This is called the handover initiation part of the handover decision phase. This part of the decision phase is unique for each handover process, and therefore no handover aspects are relevant.

If a handover request is issued, calculations will be done to determine the identification of the handover control point (handover cases), the type of the handover and the handover completion constraints. This is called the handover calculation part of the decision phase. The handover aspect that is relevant in this phase is the bearer type. This handover aspect is relevant because its information is needed to determine (calculate) the correct handover type. The exact relationship between the bearer types and the handover types has not been standardised yet. For this reason, it is assumed that each combination of bearer type and handover type can occur.

### 4.4.3 Execution phase

During this phase of the handover process the setting up, the switching between, and the release of bearers is taken care of. The handover aspects that are relevant in this phase of the handover process are the handover cases and the handover types. For this reason the handover execution part has been divided into the handover cases part and the handover types part.

In the case a radio link with a higher quality is detected, the needed handover case is an intra BTS handover. In the case the user is roaming out of the range from a BTS to another BTS, the needed handover case is an inter BTS handover, assuming that both BTSs are connected to the same Cell Site Switch (CSS). If not, but the BTSs are connected to the same Local Exchange (LE), the needed handover is an inter CSS handover. If the BTSs belong to different environments, the needed handover is an inter environment handover.

In the case the delay of the handover process is very critical, and the data losses are not, the needed handover type will be the non-seamless hard handover. In the case that losses of data may not occur, the needed handover type will be a seamless hard handover. In the case that macrodiversity can be used, the needed handover type will be a soft handover.
Figure 4-3 presents the complete Handover Generic Model. 

<table>
<thead>
<tr>
<th>Mobile Terminal</th>
<th>Network</th>
<th>Mobile Terminal and Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>MI</td>
<td>SHRU</td>
<td>SHRN</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Handover Initiation</th>
<th>Speech</th>
<th>Unconstrained delay</th>
<th>Constant bitrate</th>
<th>Variable bitrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intra BTS handover</td>
<td>Inter BTS handover</td>
<td>Inter CSS handover</td>
<td>Inter LE handover</td>
<td>Inter environment handover</td>
</tr>
<tr>
<td>Non-seamless hard handover</td>
<td>Seamless hard handover</td>
<td>Soft handover</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This model identifies 27 modules with which 660 different handover scenarios can be performed. The 27 modules are the blocks, depicted in the figure. The handover scenarios that can be performed are:

- Three scenarios with respect to the handover initiation points;
- Eleven scenarios with respect to the handover initiation procedures;
- Four scenarios with respect to the bearer types;
- Five scenarios with respect to the handover cases;
- Three scenarios with respect to the handover types;

This results in \((1 \times 3 + 1 \times 4 + 1 \times 4) \times 1 \times 4 \times 5 \times 3 = 660\) handover scenarios (Figure 4-3).

4.5 Conclusions

The handover aspects demand different scenario's to perform a handover. To efficiently implement the handover functionality, a model of the handover functionality is needed that can handle all possible handover scenarios. This chapter described the development of such a model: the Handover Generic Model. Accordingly, the impact of the handover aspects on the handover application protocol and the relationships between the handover aspects and the identified phases of the handover process have been described. The Handover Generic Model reduces the complexity of the handover functionality: 660 different handover scenarios can be performed, using 27 distinct modules.
This chapter describes the allocation of the Functional Entities (FEs) of the MONET Handover Functional Model onto the Functional Groups of the public metropolitan high traffic environment. The handover aspects described in chapter three are taken into account with respect to this allocation. Furthermore, the logical connections between the Functional Entities are described.

The assumptions that have been made are described in section 5.1. The allocation of the FEs has been described in section 5.2-4 according to the phases of the handover process in which they are active.

5.1 Assumptions

The UMTS reference configurations and the Functional Groups (FGs) that are foreseen in the reference configurations are described in chapter three. These reference configurations are valid for either the public, business or domestic environment as described in chapter 2 (section 2.3.2). Each environment demands a specific allocation of Functional Entities (FEs) onto the FGs, described in [MONET 71, MONET 73]. These specific allocations of the handover FEs demanded by the environments, do not affect their functionality. Consequently, the specific allocations of the environments do not affect the definition of the generic model for handover. Hence, the environments have not been taken into consideration.

As an example, this section will describe the allocation of the handover FEs onto the FGs of the public metropolitan high traffic environment and the logical connections between the FEs. Logical connections between two entities exist if there is a signalling relation between them.

The FEs Control Point Transfer (CPT), ReRouting Trigger (RRT), and Handover Security and Encryption (HSE) are not allocated. The CPT entity is used in the case of inter Local Exchange (LE) or inter environment handovers, which are not considered in this study. The RRT entity is used in the case an interconnection of two identical FGs has been used during a handover process. In this study interconnected FGs have not been taken into consideration (chapter two). The handover related security functions (HSE) have not been taken into account either.

The configuration of this environment onto which the allocation takes place, is a configuration in which the Base Transceiver Stations (BTSs) are connected to a Cell Site Switch (CSS) providing concentration and local switching for handover. The mobility control takes place in the Mobile Switching Control Point (MSCP) of the Radio Access System (RAS) (Figure 3-5).

The Handover Generic Model will be used in order to describe the allocation of the handover FEs. This Model divides the handover process into three phases and relates the handover aspects to those phases. Consequently, it provides a structure which is used to describe the way the handover aspects affect the allocation of the FEs.
5.2 Information Gathering Phase

The allocation of the FEs and the logical connections between the FEs, active during the information gathering phase depends on the number of the handover initiation points in the network and where they are situated.

Two groups of handovers with respect to the handover initiation points have been identified (chapter three). In the first group there is a single handover initiation point and the initiation of a handover process is taken either in the Mobile Terminal (MT) or in the network. In the second group there are two possible initiation points and both the mobile station and the network can initiate a handover process.

The entities which allocation is described are the entities involved in the information gathering phase: MEasurement Function (MEF), Target Cells and Connections - User (TCCU), Handover User Profile - User (HUPU), Special Handover Request - User (SHRU), Handover Criteria (HC), and Handover Criteria Adjustment (HCA). To clarify the logical connections between the entities, the Handover Initiation (HI) entity involved in the handover decision phase is also allocated. Note that the description of the functionality of the entities is given in chapter three.

5.2.1 Single handover initiation point

In the case of a single handover initiation point, only one HI entity is allocated. In this configuration four procedures have been distinguished: Mobile Initiated (MI) handover, Network Initiated (NI) handover, Mobile Assisted (MA) handover, and Special Handover Request issued by the User (SHRU). Each procedure requires information that is acquired by and stored in the MT.

The information about which cells the MT can access and their related information is acquired by the TCCU entity. This information is needed in each procedure and is only useful if it is acquired by the MT. Hence, the TCCU entity is always allocated in the MT.

The subscriber related information is stored in the HUPU entity. This entity is involved in each procedure and is always allocated in the MT.

The information about the handover criteria is represented by the HC entity. This entity is allocated close to the HI entity (in the same network entity), due to performance reasons. The HC entity is set and updated by the HCA entity. The latter entity is allocated in the MSCP (Access) according to the Intelligent Network (IN) concept.

The following paragraphs describe the allocation of the FEs and the logical connections between the FEs involved in the information gathering phase for the concerned procedure.

Initiation point in Mobile Terminal

To initiate a handover, the MT requires a MEF entity that performs downlink measurements on the radio link. This information together with the information originating from the HUPU, TCCU, and HC entities must be processed by a HI entity, to enable a Mobile Initiation (MI) of handover by the MT. Therefore, the HI entity in this procedure is allocated in the MT. This is depicted in Figure 5-1.
The special handover request issued by the user requires a SHRU entity in the MT to receive requests from the user and to forward them to the HI entity. In the case that the handover initiation point is located in the MT, the SHRU entity is logically connected to the HI in the MT. The allocation of the FEs is depicted in Figure 5-2.

Handover initiation point in the network

To initiate a handover, the network requires a MEF entity to perform uplink measurements on the radio link. These measurements are done on the radio link, and therefore this entity is allocated in the BTS. The initiation of the handover requires information from the HUPU, TCCU, and HC entities. As mentioned earlier, the HUPU and the TCCU entities are always allocated in the MT. The HC entity will be allocated close to the HI entity. The handover initiation point (HI entity) has to be located in the network, to enable Network Initiated (NI) handovers. To efficiently process the information originating from the entities mentioned before, the HI entity is allocated in the BTS. The allocation of the FEs is depicted in Figure 5-3.
The special handover request issued by the user requires a SHRU entity in the MT to receive requests from the user and to forward them to the HI entity. In the case that the handover initiation point is located in the BTS, the SHRU entity is logically connected to the HI in the BTS. This is depicted in Figure 5-4.

The initiation of a Mobile Assisted (MA) handover implies that the network has to monitor both the uplink and the downlink radio link. The quality of the uplink is measured by a MEF entity in the BTS. The quality of the downlink is measured by a MEF entity in the MT. This is depicted in Figure 5-5.
5.2.2 Two handover initiation points

In the case of two handover initiation points, two HI entities are allocated: one in the MT to process the information gathered in the MT, and one in the BTS to process the information gathered in the BTS. Both HI entities process the gathered information and are able to initiate a handover process. During the handover initiation process, the HI entity that determined the need for a handover will notify the second HI entity to indicate that a handover initiation has occurred in a specific part of the UMTS system. The interconnection of the two HI entities can also be used to pass information about candidate cells from the MT towards the network. Three procedures have been identified: mobile originated handover, network originated handover, and special handover request issued by the user.

To initiate a handover process, both the MT and the BTS have to gather information about the current status of the active radio link. This is done by the MEF entities, allocated in both the MT and the BTS. The TCCU and HUPU entities are allocated again in the MT. The initiation of the handover process requires information about the handover criteria used in the handover process. This information is stored in the HC entity, and is allocated close to each HI entity. Figure 5-6 depicts the allocation of the FEs needed in both mobile initiated and network initiated handovers.

Figure 5-6: FEs needed during the information gathering phase for MO and NO handovers
The special handover request issued by the user requires a SHRU entity that is allocated in the MT and is logically connected to the HI entity in the MT. If the SHRU entity detects a special handover request from the user, it will forward this request to the HI entity allocated in the MT. This HI entity will notify the other entity that a handover process is going to be initiated. The allocation of the FEs is depicted in Figure 5-7.

![Figure 5-7: FEs needed during the information gathering phase for SHRU, HI in MT and BTS](image)

The allocation and interconnection of the FEs needed in the information gathering phase, valid for each procedure, is depicted in Figure 5-8.

![Figure 5-8: FEs needed during the information gathering phase](image)

### 5.3 Decision Phase

The allocation of the FEs, active during the decision phase depends on whether the handover is initiated by the HI entities, or whether a special handover request from the network has been received.

In the first situation, one of the two HI entities has processed the information gathered in the previous phase and as a result of that it has issued a handover request to the Handover Decision (HD) entity. This entity is allocated in the MSCP (Access), because all mobility control is situated in this functional group, in accordance to the IN concept. The HD entity decides whether or not a handover is going to be executed. To do so, it negotiates about a possible service degradation by using information from the Target Cells and Connections Network (TCCN) entity and Handover User Profile -
Network (HUPN) entity. Due to performance reasons, these entities are allocated close to the HD in the MSCP (Access).

In the second situation, the HD entity receives a forced handover request from the Special Handover Request - Network (SHRN) entity. The SHRN entity is for the same reason allocated in the MSCP (Access).

Note that the signalling association, the interface, between the HD entity and the HI entity in the MT is identical to the interface between this HD entity and the HI entity in the BTS.

Both situations are depicted in Figure 5-9. The entities needed during the information gathering phase are depicted in grey. The entities needed during the decision phase are depicted in white.

![Figure 5-9: FEs needed during the decision phase](image)

5.4 Execution Phase

The allocation of the FEs, active during the execution phase depends on the handover cases and the handover types.

5.4.1 Handover cases

The handover cases that are considered are intra BTS handover, inter BTS handover and inter CSS handover.

Intra BTS handover

As described earlier, the intra BTS is the least complex handover case. This handover case is completely handled by the Radio Bearer Control (RBC) entities. These entities are allocated close to the radio interface; at the MT and the BTS. The RBC entities are responsible for the detection for the need for an intra BTS handover, the decision to execute, and the execution itself. No other entities are involved. This is depicted in Figure 5-10.
Inter BTS handover

If the HD entity decides to execute an inter BTS handover, it will trigger the HandOver Control (HOC) entity to take control of the execution of the handover. The HOC entity is allocated at the MSCP (Access), in accordance with the IN concept. The Bearer Control (BC) entity is allocated in the CSS to enable the set up of new bearers and the release of old bearers in the CSS. The BC entity is controlled by the HOC entity. This is depicted in Figure 5-11. Note that the entities, needed during the previous phases are depicted in grey.

Inter CSS handover

In case there is a CSS-CSS connection in the UMTS network architecture, there are two possibilities for the inter-CSS handover. One possibility is to use the CSS-CSS connection, whereas the other is to use the CSS-LE-CSS connections; the same one as is used when the CSS-CSS connection does not exist.

If the HD entity decides to execute an inter CSS handover, it will trigger a HOC entity to take control of the execution of the handover. Suppose the CSS-CSS connection does not exist, or is not available. The HOC entity that will be triggered, is allocated at the MSCP (Core), in accordance with the IN concept. To enable the set up and release of bearers, BC entities have to be allocated in the LE and in the CSS, and RBC entities have to be allocated in the MT and BTS. This is depicted in Figure 5-11. Again, the entities, needed during the previous phases are depicted in grey.
5.4.2 Handover types

After new bearers have been set up, and before the old bearers can be released, the actual switching will have to take place. The way this is done, is defined by the handover types. In chapter three two basic handover types have been identified, hard handover and soft handover.

Hard handover

Two kinds of hard handover have been identified, non-seamless hard handover and seamless hard handover. Both kinds of hard handover make use of the Switching and Bridging Control (SBC) entity. The switching between bearers takes place in both the MT and the network. Hence, the SBC is allocated in both the MT and the network. In the case of an inter BTS handover the SBC will be allocated in the CSS (and in the MT). In the case of an inter CSS handover the SBC will be allocated in the LE (and in the MT). This is depicted in Figure 5-13, for both handover cases.

Soft handover

During a soft handover two parallel paths are active at the same time. In the MT this requires combining of the information received from the downlink, and multicasting the information over the two (or more) uplinks. In the network the combining and multicasting functionalities are the opposite. These combining and multicasting
functionalities are performed by the Combining and MultiCasting (CMC) entity. This entity has to be allocated in both the MT and the network. In the case of an inter BTS handover the CMC will be allocated in the CSS (and in the MT). In the case of an inter CSS handover the CMC will be allocated in the LE (and in the MT). This is depicted in Figure 5-13, for both handover cases.

Figure 5-14: FEs needed for soft handover, both for inter BTS and inter CSS handover

5.5 Conclusions

The allocation of the Functional Entities of the MONET Handover Functional Model onto the Functional Groups of the public (metropolitan) high traffic environment results in the figure depicted below. The Handover Generic Model has been used in this allocation, in order to describe the way the aspects of the handover process affect the allocation of the FEs.

The logical connections between the Functional Entities show the possible signalling associations between the entities, valid for each handover aspect. If the handover related security functions are taken into account it may be necessary to make usage of the MSDP (Access). This can result in different allocations of the handover Functional Model.

The resulting allocation and interconnection of FEs has been depicted in Figure 5-15.

Figure 5-15: Allocation and interconnection of FEs of the MONET Handover Functional Model onto the FGs of the public (metropolitan) high traffic environment
The allocation of the Functional Entities (FEs) and their signalling associations have been discussed in the previous chapter. This chapter characterises these (signalling) relations arising among the FEs, by describing the protocols needed between Functional Groups. These are derived from the Information Flows (IFs), which are used to describe the needed interaction between two FEs as to support their joint operation. FPs are normally implemented at the application layer, but in order to fulfil the performance requirements for handover, they might also be implemented at lower layers. In section 6.1 the basic protocol model for UMTS is shortly described. In this section the top-level structure of the handover information flows is presented. The handover information flows are described in section 6.2-4 according to the phases of the handover process in which they can be needed.

6.1 Basic protocol model

The protocol model used for the UMTS Access network (MT and Radio Access System) is based on the concepts of the OSI Reference Model, but only uses four layers [MONET 65]. The basic structure of the layering is shown in Figure 6-1.

<table>
<thead>
<tr>
<th>Application Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Layer</td>
</tr>
<tr>
<td>Data Link Layer</td>
</tr>
<tr>
<td>Physical Layer</td>
</tr>
</tbody>
</table>

Figure 6-1: Basic protocol model of the UMTS Access Network

This model is the same as is used in Signalling System number 7. The functions of the different layers correspond to those defined for the same layer in the OSI Reference model. The lowest three protocols, Network Layer to Physical Layer, provide the means to transport Application Layer signalling between various control functions implemented as signalling applications.

The signalling associations between FEs within a Functional Groups (FG, chapter 5) can be seen as signalling relations within the application layer of the particular FG. The signalling associations between FEs of different FGs can be seen as signalling relations between the application layers of the FGs. Only the relations between Bearer Control entities (BCs and/or RBCs) are lower layer relations. The messages that are exchanged between the FEs within the application layer or between application layers are referred to as the handover application protocol.

The handover IFs provide a top-level structure of this handover application protocol. The protocol has been divided according to the phases identified in the handover process. From the description of the Handover Generic Model (chapter
4) can be seen, that a structure as given in Figure 6-2 suffices to handle all possibilities of the handover process.

![Figure 6-2: Top-level structure of the handover information flows](image)

The boxes in the figure indicate relevant IFs that are exchanged between entities during the performance of a particular aspect of the handover process.

The subsequent sections describe the handover IFs of each handover phase.

6.2 Information gathering phase

The handover aspects that are relevant in the handover information gathering phase are the number of initiation points the system has been equipped with and the way the handover process has been initiated. For this reason description of the handover information phase has been divided into two parts: handover initiation points and handover initiation procedures.

6.2.1 Handover initiation points

The first handover aspect that is relevant in the handover information gathering phase is the number of handover initiation points with which the system has been equipped. During this part of the handover information gathering phase, the information needed by the Handover Initiation (HI) entity for each handover procedure has been exchanged. This involves communication between the HI entity (or HI entities) and the Handover User Profile - User (HUPU) and Target Cells and connections - User (TCCU) entities.

The first section describes the IFs used during the handover information gathering phase, in a single handover initiation point configuration. The second section describes the IFs used during the handover information gathering phase in a two handover initiation points configuration.

6.2.1.1 Single handover initiation point

As described earlier, the initiation point (HI entity) in this configuration can be allocated in the Mobile Terminal (MT), or in the Base Transceiver Station (BTS) (chapter 4). The communication between the HI, HUPU, and TCCU entities for both HI entity allocations has been depicted in Figure 6-3. The situation in which the HI entity has been allocated in the BTS, and the HUPU and TCCU entities have been allocated in the MT is indicated by arrow A. The situation in which the HI, HUPU, and TCCU entities have been allocated in the MT is indicated by arrow B.
The TCCU entity provides the HI entity with a list of candidate base stations, possibly connection information, and relevant quality parameters. This information is sent to the HI entity with the CAND_LIST_REPORT message. Subsequently, the HI entity will request the HUPU to send the subscriber-related information, that is relevant to the handover process (bandwidth requirements, QoS requirements, access rights, priorities, environment selection, operator selection, preference list, etc.). The HI entity needs this information in order to evaluate it during the handover process. The messages that are used are the USER_DATAreq_ind message (the request) and the USER_DATAresp_conf message (the response).

After these IFs have been exchanged, the handover process enters the situation in which information can be gathered for a specific handover initiation procedure.

6.2.1.2 Two handover initiation points

In this configuration both HI entities gather information from the HUPU and TCCU entities. After these IFs have been exchanged, the handover process enters the situation in which information can be gathered for a specific handover initiation procedure. This is depicted in Figure 6-4.

6.2.2 Handover initiation procedures

The IFs exchanged during this part of the information gathering phase depends on the number of handover initiation points, and the handover initiation procedures.
The first section describes the IFs needed in a single initiation point configuration for each identified handover initiation procedure. The second section describes the IFs needed in a two initiation points configuration.

6.2.2.1 Single initiation point

As described earlier, the handover initiation procedures identified in this configuration are Mobile Initiated (MI) handover, Network Initiated (NI) handover, Mobile Assisted (MA) handover, Special Handover Request issued by the User (SHRU), and Special Handover Request issued by the Network (SHRN). The IFs needed by these procedures are described in the following paragraphs.

Mobile/Network initiated handover

This handover initiation procedure is used, when either the MT or the network detects the need for a handover due to radio link criteria. For this reason, the HI entity needs information about the active radio path. This information is provided by the MEasurement Function (MEF) entity. This entity performs measurements concerning a specific active radio link and forwards the measurements to the HI entity in a defined form on a regular short-term base. The message that is used for this purpose is the \textit{LINK\_QUALITY\_REPORT} message.

Furthermore, the HI entity needs information about the Handover Criteria (HC) that are used in the handover process. Hence, the HI entity will request the Handover Criteria (HC) entity to send an update of these criteria. The HC entity will respond by returning the quasi static parameters that represent the handover criteria. The messages that are used are the \textit{HO\_CRITERIA_req_ind} message (the request) and the \textit{HO\_CRITERIA_resp_conf} message (the response).

This is depicted in Figure 6-5. Note that the three entities discussed are either located in the MT or in the BTS.

The HI entity will process the information gathered during the information gathering phase and if it determines that a handover is needed, it will issue a request for handover to the Handover Decision (HD) entity. This is discussed in the section that describes the handover decision phase.

![Figure 6-5: Mobile/Network initiated handover (single initiation point)]
Mobile assisted handover

This handover initiation procedure is used, when both the MT and the network are equipped with a MEF entity, but only the network is equipped with a handover initiation point. Both MEF entities will send information about the quality of the (uplink or downlink) current link to the HI entity, which responds by requesting the HC entity to send an update of the Handover Criteria (HC). This is depicted in Figure 6-6.

The HI entity will process the information gathered during the information gathering phase and if it determines that a handover is needed, it will issue a request for handover to the HD entity. This is discussed in the section that describes the handover decision phase.

Special Handover Request User

If the user requests a handover, the SHRU entity will issue a Special Handover Request issued by the User to the HI entity. The HI entity will not gather any more information, because all the information needed is included in the IF from the SHRU entity to the HI entity. This is depicted in Figure 6-7.

After the reception of the SHRU, the HI entity will issue a request for handover to the HD entity. This is discussed in the section that describes the handover decision phase. When the Handover Decision Phase has been completed, the HI entity will receive a confirmation of its request for handover to the HD entity, mentioned earlier. As a response on that reception, the HI entity will send a confirmation to the SHRU entity whether the SHRU has been successfully performed or not.
The messages that are used are the SPEC_HO_REQ_USERreq_ind message (the request) and the SPEC_HO_REQ_USERresp_conf message (the confirmation).

**Special Handover Request Network**

If the network requests a handover, the SHRN entity will issue a Special Handover Request from the Network (SHRN) to the HD. The HD will forward this request to the HI entity in the BTS. If no HI entity is present in the BTS, it will forward it to the HI entity in the MT. The HI entity will not gather any more information, because all the information needed is included in the IF from the HD entity to the HI entity (and the IF from the SHRN entity to the HD entity). This is depicted in Figure 6-8.

![Figure 6-8: Special Handover Request Network (single initiation point)](image)

After the reception of the SHRN, the HI entity will issue a request for handover to the HD entity. This is discussed in the section that describes the handover decision phase. When the Handover Decision Phase has been completed, the HI entity will receive a confirmation of its request for handover to the HD entity, mentioned earlier. As a response on that reception, the HI entity will send a confirmation to the SHRN entity whether the SHRN has been successfully performed or not.

The messages that are used are the SPEC_HO_REQ_NETWreq_ind message (the requests) and the SPEC_HO_REQ_NETWresp_conf message (the confirmations).

**6.2.2.2 Two initiations points**

As described earlier, the handover initiation procedures identified in this configuration are Mobile Originated (MO) handover, Network Originated (NO) handover, Special Handover Request issued by the User, and Special Handover Request issued by the Network. The IFs needed by these procedures are described in the following paragraphs.

**Mobile/Network originated handover**

This handover initiation procedure is used, when either the MT or the network detects the need for a handover due to radio link criteria. Both the MT and the BTS are equipped with the MEF, HC, and HI entities. This implies that both the MT and the network can initiate a handover.

For this reason, both the MEF entities will send information about the quality of the current link to the HI entity that is allocated in the same NE. The HI entities
respond by requesting the HC entity (in the same NE) to send an update of the HC.

Both HI entities will process the information gathered during the information gathering phase. Suppose that the HI entity in the MT determines that a handover is needed. In that case, it will inform the HI entity in the BTS about that occurrence. The HI entity in the BTS will answer this notification with a confirmation. This is depicted in Figure 6-9. Note that the situation in which the HI entity in the BTS determines the need for a handover is identical to the situation described before. In this situation the IFs between the HIs will be reversed.

![Figure 6-9: Mobile originated handover (single initiation point)](image)

After the HI entity has notified the other HI entity, and has received the confirmation from this entity, it will issue a request for handover to the HD entity. This is discussed in the section that describes the handover decision phase. When the Handover Decision Phase has been completed, the HI entity that issued the handover request will send a notification to the other HI entity whether the handover has been successfully performed or not. The other HI will confirm this notification.

The messages that are used are the `HO_INITIATION_INDreq_ind` message (the notification), the `HO_INITIATION_INDresp_conf` (the confirmation), the `HO_COMPLETEreq_ind` (the notification), and the `HO_COMPLETEresp_conf` (the confirmation).

**Special handover request user:**

If the user requests a handover, the SHRU entity will issue SHRU to the HI entity in the MT. This HI entity will not gather any more information, because all the information needed is included in the IF from the SHRU entity. The HI entity in the MT will inform the HI in the BTS about this occurrence. This HI entity will respond with a confirmation. This is depicted in Figure 6-10.

After the reception of the confirmation of the HI entity in the BTS, the HI entity in the MT will issue a request for handover to the HD entity. This is discussed in the section that describes the handover decision phase. When the Handover Decision Phase has been completed, the HI entity in the MT will receive a confirmation of its request for handover to the HD entity, mentioned earlier. As a response on that reception, the HI entity in the MT will send a notification to the HI entity in the BTS.
whether the handover has been successfully performed or not. This HI will confirm
this notification. As a response on this confirmation, the HI entity in the MT will
send a confirmation to the SHRU entity whether the SHRU has been successfully
performed or not.

![Diagram](image)

Figure 6-10: Special handover request user (two handover initiation points)

Special handover request network:

If the network requests a handover, the SHRN entity will issue a SHRN to the HD.
The HD will forward this request to the HI entity in the BTS. This HI entity will not
gather any more information, because all the information needed is included in the
IF from the HD entity to the HI entity (and the IF from the SHRN entity to the HD
entity). The HI entity in the BTS will inform the HI entity in the MT about this
occurrence, which will respond with a confirmation. This is depicted in Figure 6-11.

![Diagram](image)

Figure 6-11: Special handover request network (two handover initiation points)

After the reception of the confirmation of the HI entity in the MT, the HI entity in
the BTS will issue a request for handover to the HD entity. This is discussed in the
section that describes the handover decision phase. When the Handover Decision
Phase has been completed, the HI entity in the BTS will receive a confirmation of
its request for handover to the HD entity, mentioned earlier. As a response on that
reception, the HI entity in the BTS will send a notification to the HI entity in the MT
whether the handover has been successfully performed or not. This HI will confirm this notification. As a response on this confirmation, the HI entity in the BTS will send a confirmation to the SHRN entity whether the SHRN has been successfully performed or not.

6.3 Handover decision phase

During the handover decision phase no handover aspects (as described in chapter three) are relevant with respect to the information flows. This implies that the decision process about whether a handover should be initiated or not and how the handover is going to be executed is unique. The decision phase has been divided into two parts: the handover initiation part and the handover calculation part.

6.3.1 Handover initiation

In this part of the decision phase, the HI entity processes the information gathered during the previous phase. As a result of this the entity decides whether or not a handover should take place. If it has decided that a handover should take place, it determines how the handover should ideally be performed. Subsequently, the HI entity will issue a request for handover to the HD entity. At this point, the calculation part of the handover decision phase will be entered. This is depicted in Figure 6-12.

![Figure 6-12: Handover initiation](image)

When the handover calculation part has been completed, the HI entity will receive a confirmation of its request for handover from the HD entity, indicating whether the handover has been successful or not.

The messages that are used are the `HO_INIT_REQreq_ind` message (the request) and the `HO_INIT_REQresp_conf` message (the confirmation).

6.3.2 Handover calculation

During the handover calculation part of the decision phase the HD entity determines the optimal handover procedure in a specific situation. Prior to this determination the HD entity will consult the Handover User Profile - Network (HUPN) and Target Cells and Connections - network (TCCN) entities. Firstly, the HD entity will request the subscriber profile and the service profile from the HUPN entity. This information is used by the HD entity to determine possible service degradations, e.g. bandwidth requirements, Quality Of Service (QoS) requirements, etc.. If the HD entity has received this information from the HUPN entity, it will request information about the availability of a number of fixed resources from the TCCN entity. This information is again used to determine...
possible service degradations, e.g. maximum delay, urgency, etc.. If the optimal handover procedure has been completed successfully, the HD entity will request the HandOver Control (HOC) entity to take control of the handover process. If the handover can be performed at Cell Site Switch (CSS) level, the HOC in the MSCP(Access), the Mobile Service Control Point (MSCP) in the Radio Access System (RAS), will be involved. Otherwise, if the handover can only be performed at Local Exchange (LE) level, the HOC at the MSCP(Core), the MSCP in the Core network, will be involved. This is depicted in Figure 6-13.

When the Handover Execution Phase has been completed, the HOC entity will send the result of the handover process to the HD entity.

The messages that are used are the SERVICE_DATAreq_ind message (request to the HUPN), the SERVICE_DATAresp_conf message (response from the HUPN), the RESOURCE_INFOreq_ind message (request to the TCCN), the RESOURCE_INFOresp_conf message (response from the TCCN), the HANDOVER_CONTROLreq_ind message (request to the HOC), and the HANDOVER_CONTROLresp_conf message (result from the HOC).

6.4 Execution phase

The handover aspects that are relevant in the handover execution phase are the handover cases and the handover types. For this reason the handover execution phase has been divided into two parts: handover cases and handover types.

6.4.1 Handover cases

The first handover aspect that is relevant in the handover execution phase is at which network level (BTS, CSS, LE) the handover process can be performed. During this part of the handover execution phase new bearers are set up, and the old ones released. This involves communication between the HOC, Bearer Control (BC), and Radio Bearer Control (RBC) entities.

As described in chapter three, the handover cases that are taken into account are inter BTS handover and inter CSS handover. The first section describes the IFs involved during an inter BTS handover. The second section describes the IFs involved during an inter CSS handover.
Inter BTS handover

The execution phase is entered by the request from the HD entity to the HOC entity in the MSCP(Access). The HOC entity takes the control of the handover process and sends a request for new bearers to the BC entity in the CSS. The BC entity in the CSS will forward this request to the RBC entity in the BTS. This BTS will set up a new radio path to the MT. The RBC entity in the BTS will be notified by the RBC entity in the MT whether the link has been established. This RBC entity will forward this notification to the BC entity in the CSS, which will forward it to the HOC entity. After the actual switching has taken place, during the handover type part of the execution phase, the HOC entity will request the release of a particular bearer. This procedure is identical to the set-up procedure described above. Figure 6-14 depicts the IFs involved in the part of the execution phase.

![Diagram of Inter BTS handover](image)

The messages that are used are the `CONNECTreq_ind` message (new bearer set-up request), the `CONNECTresp_conf` message (result of the set-up of the new bearer), the `RELEASEreq_ind` message (old bearer release request), and the `RELEASEresp_conf` message (result of the release of the old bearer).

Inter CSS handover

This case is identical to the inter BTS handover case, with two important differences: the activated HOC entity is the HOC entity at LE level, and the BC entity in the LE is also involved in the set-up and release of bearers. This is depicted in Figure 6-15.
6.4.2 Handover types

The actual switching in the handover process takes place in this last part of the handover execution phase. The handover aspect that is relevant in this part of the handover process is the handover type. The identified handover types are non-seamless hard handover, seamless hard handover, and soft handover. The IFs involved in the execution of these handover types are described in the following paragraphs.

**Non-seamless hard handover:**

This handover type switches from the old bearer to the new bearer, without taking care that data will not be lost on the old path. This handover type involves communication between the HOC entity and the SBC entities. The HOC entity will instruct the Switching and Bridging Control (SBC) entity in both the CSS (or LE depending on the handover case) and the MT to switch from the old path to the new path. When the switching has been performed, the SBC will confirm the HOC entity about that. This is depicted in Figure 6-16.

The messages that are used are the `SWITCH_CONNreq_ind` message (the request) and the `SWITCH_CONNresp_conf` message (the confirmation).
Seamless hard handover

This handover type takes care of the data lost on the old path during the switching between bearers. For this reason the HOC entity requests the SBC entities to set up a bridge in both the MT and the CSS (or LE depending on the handover case). After the HOC entity has received the confirmations of the SBC entities indicating that the bridges have been set up, the entity will request the SBC entities to switch to the new bearers. After the HOC entity has received the confirmations of the SBC entities indicating that the switching has taken place, the entity will request the SBC entities to release their bridges. This is depicted in Figure 6-16.

Soft handover

This handover type adds bearers to and removes bearers from a particular connection. No switching takes place. This handover type involves communication between the HOC entity and the Combining and Multicasting Casting (CMC) entities.
in both the CSS (or LE depending on the handover case) and the MT. To perform a soft handover, the HOC entity will request both the CMC entities to add a new bearer to a particular connection. After the HOC entity has received the confirmations of the CMC entities indicating that the new bearer has been added to the connection, the entity will request the CMC entities to remove the bearer with the worst properties from the connection.

The messages that are used are the ADD_CONNreq_ind message (the request for the addition of a bearer), the ADD_CONNresp_conf message (the confirmation of the addition of a new bearer), the DROP_CONNreq_ind message (the request for the removal of a bearer), and the DROP_CONNresp_conf message (the confirmation of the removal of a bearer). This is depicted in Figure 6-18.

![Figure 6-18: Soft handover](image)

### 6.5 Conclusions

This chapter characterises the (signalling) relations arising among the Functional Entities, by describing the Information Flows. These Information Flows are used to describe the needed interaction between two Functional Entities as to support their joint operation. This resulted in the development of a top-level structure of the handover Information Flows that is suitable for all handover scenarios.

These Information Flows are used by the processes that are specified in order to verify the feasibility of the Handover Generic Model (Appendix A).
The Handover Generic Model is a model of the handover functionality that is suitable for all handover scenarios. The common features of the handover scenarios have been studied, resulting in the identification of handover aspects. This chapter explores the applicability of the Handover Generic Model. Hence, the Model has been verified and its coverage with respect to all handover scenarios has been studied. The verification of the Model is done by formulating SDL specifications of the handover application protocol. Section 7.1 will introduce the reader to modelling in SDL. The verification of the Model is described in section 7.2. The coverage of the Model has been studied by describing the assumptions that have been taken into consideration and by describing the options of the handover aspects that have not been studied. The coverage of the Model is described in section 7.3.

7.1 Modelling in SDL

SDL is a standard language for specifying and describing systems. It has been developed and standardised by ITU-T in the recommendation [Z.100]. SDL is used for formal description of mainly telecommunication systems. The version of SDL used in this report is SDL'92.

An SDL specification (an SDL system) consists of a number of interconnected modules (blocks). A block can recursively be divided into more blocks forming a hierarchy of blocks. The channels define the communication paths through which the blocks communicate with each other or with the environment. Each channel usually contains an unbounded FIFO (First In First Out) queue that contains the signals that are transported on the channel. The behaviour of the leaf blocks is described by one or more communicating processes. The processes are described by extended finite state machines.

7.1.1 Theoretical model

An SDL system consists of a set of extended Finite State Machines (FSM) that run in parallel. These machines are independent of each other and communicate with discrete signals. An SDL system consists of the following four components [SDT 3.0]:

- **Structural view**: System, block, process, and procedure hierarchy;
- **Communication**: Signals with optional signal parameters and channels;
- **Behaviour**: Processes;
- **Data**: Abstract data types.

These components will be described shortly.

**Structural View**

Figure 7-1 depicts the four main hierarchical levels in SDL.
The system view depicts the refinement of the system into blocks. In Figure 7-1, these blocks are named Bi1 and Bi2.

The block view depicts the refinement of the system blocks into processes. In Figure 7-1, these processes are named Pr1 and Pr2.

The process view depicts the finite state machines that perform the functionality of the particular FE.

Finally, the procedure view depicts the finite state machines that are used by the processes.

**Communication**

In SDL, there is no global data. This approach requires that information between processes, or between processes and environment, must be sent with signals and optional signal parameters. Signals are sent synchronously; the sending process continues executing without waiting for an acknowledgement from the receiving process.

**Behaviour**

The dynamic behaviour in an SDL system is described in the processes. The block hierarchy is only a static description of the system structure. Processes in SDL can be created at system start, or created and terminated at runtime. More than one instance of a process can exist.

**Abstract Data Types**

The abstract data types concept in SDL is very well suited to a specification language. An abstract data type is a data type with no specified data structure. Instead, it specifies a set of equations that the operations must fulfil.

The software tool that is used for SDL specifications at KPN Research is the SDL Definition Tool (SDT) version 3.0. SDT not only provides a graphical design editor and analyser, but also a tool that can be used for simulation of the design. The simulator provides output as information flow diagrams, that are suited for elaboration of the developed SDL system.
7.1.2 The MSC language

ITU has standardised a formal language that defines Message Sequence Charts (MSCs). As defined in the recommendation [Z.120], the MSC language offers a powerful complement to SDL in describing the dynamic behaviour of an SDL system. Its graphical representation is well suited for presenting a complex dynamic behaviour in a clear and unambiguous way.

An MSC describes one or more traces from one node to another node of an abstract communication tree generated from an SDL specification. Basically, the information interchange is carried out by sending messages from one instance to another. In an SDL specification, those messages would coincide with the signals that are sent from one process and consumed in another process. The instances would correspond to any part of the specification (an SDL system, a block, or a process).

In this study, the MSC language has been used to present a graphical output of the execution of the simulations of handover processes. These simulations are necessary, in order to verify the Handover Generic Model. To do so, these MSCs have been compared with the information flows, as described in chapter six. Some MSC charts that resulted from the simulations can be found in Appendix B.

7.2 Verification Handover Generic Model

The Model has been verified by formulating SDL specifications of a minimum number of processes with which all identified aspects of the handover process can be simulated. The formulated specifications make use of the handover information flows, described in chapter six. In order to be able to verify all handover aspects, supported by the Model, the choice has been made to specify the handover functionality of one UMTS environment. The public (metropolitan) high traffic environment has been selected according to its importance (i.e., high number of users). This section describes how the UMTS system has been specified and which aspects of the UMTS system have been omitted.

7.2.1 Formulated SDL specifications

The system of the formulated SDL specifications has been divided into blocks according to the Functional Groups (FGs) encountered in this UMTS environment (as described in chapter three).

Each FG has been divided into processes according to the Functional Entities (FEs) encountered in the Handover Functional Model. The precise allocation of each FE onto the FGs, with respect to this UMTS environment, has been described in chapter five.

The signals used in the communication between the processes, the FEs, are the Information Flows (IFs) of the handover application protocol. These IFs have been described in chapter six.

The behaviour of the FEs has been formulated in such a way that each FE, if necessary, can be re-used in other FGs.

The SDL specifications that have been formulated in order to verify the Model can be found in Appendix A.1-3. Some MSC charts that resulted from the simulations can be found in Appendix B.
7.2.2 Restrictions of the SDL specifications

The main objective of the formulated SDL specifications and the simulations is the verification of the defined Handover Generic Model. This is done by means of the elaboration of an example of a UMTS environment, the public (metropolitan) high traffic environment. In order to reduce the complexity of the SDL specifications, some aspects of the UMTS environment have been omitted:

- **Switching and data processing functionality is omitted**
  The functionality of the FEs (switching of bearers, and the storing, gathering, and combining of user and control data) has not been specified. This has not been studied in this report. Only the IFs that start the execution of these functionalities and the IFs that result from that, are specified. The result of this is a high level description of the handover functionality.

- **One handover process at a time**
  The formulated SDL specifications of the UMTS system are not able to perform multiple handover processes simultaneously. The handling of multiple handovers has been no subject of study.

- **No intra BTS handovers**
  These handovers depend on the radio interface the UMTS network has been equipped with. The handling of these handovers is supposed to be performed at the lower three layers of the OSI protocol stack. This entails the invisibility of these handovers at the handover application layer. Hence, the intra BTS handovers have not been specified.

- **No inter LE and inter environment handovers**
  These handover cases have not been specified. These cases require functionality (i.e. transfer of control point) that introduces a lot of complexity.

- **No interconnection between network elements.**
  The study, described in this report, has made use of a tree topology without interconnections between network elements (FGs). The interconnections of FGs and the network topology introduce complement lower layer protocols between FGs (i.e., rerouting procedures, chapter three). These messages have no impact on the handover application layer. Hence, only the tree topology without interconnections has been studied.

- **Network errors are omitted**
  Each functionality performs correctly, and does not introduce errors nor negative results. Among other things, this entails that each request for handover (issued by the Handover Initiation (HI) entity), always results in the performance of the requested handover process. In reality, the HI entity creates a list of possible handover processes with respect to one user. The HI entity will request the Handover Decision (HD) entity to perform a handover process that is on top of this list; having the best characteristics. The HD entity will calculate whether the performance of this process is possible or not. If, i.e. the requested handover process requires too much bandwidth, the HD entity will respond with a negative result. In that case, the HI entity will continue with the request of the second handover process on its list. These requests and rejections continue until the handover has been performed, or the situation has been changed.
7.3 Coverage Handover Generic Model

The coverage of the Model has been studied by describing the assumptions that have been taken into consideration with respect to the handover aspects. Furthermore, the coverage has been studied by the identification of options of the handover aspects that have not been studied.

With respect to the handover aspects, the following assumptions have been made:

- **The radio interfaces have no impact on the application layer**
  As described in chapter three, only the lower layers of the radio interfaces are used.

- **The impact of the UMTS environments and reference configurations is limited to the allocation of the FEs.**
  The UMTS environments and reference configurations define the way the handover functionality has been allocated to the FGs of the UMTS network (chapter three). Hence, the have no impact on the handover functionality.

- **All handovers within the security control domain**
  From a security point of view, two more handover cases can be distinguished: handovers inside one security control domain, and handovers between security domains. The handover related security functions have been no subject of study, and therefore each handover is supposed to be within a particular security control domain.

Taking these assumptions into consideration, the Handover Generic Model covers all identified handover aspects, identified in chapter three. However, the different options of an handover aspect that can be used in a particular handover scenario are not all covered by the Model. Two options have not been taken into consideration:

Firstly, the handover initiation part of the handover decision phase is assumed to be unique for each handover scenario. This 'unique' part is called a backward handover. Another way to perform this part of the handover process is a forward handover. These two types, concerning the control of the handover process, have been clarified in chapter three (section 3.7). A forward handover can be performed in two cases. The first case is when the Handover Initiation (HI) entity has been allocated in the MT and the handover has been Mobile Initiated (MI), or has been requested by the network or the user (SHRN or SHRU). The other case in which a forward handover can be performed is when the HI entity has been allocated in both the MT and the network, and the handover has been Mobile Originated (MO).

These options do not require any new Information Flows between entities. Therefore, these handover types, concerning the control of the handover process can easily be added to the Handover Generic Model.

Secondly, the execution of the hard handover type is assumed to be possible in two ways: seamless and non-seamless. With respect to this handover type, it has been assumed that there is sufficient time for the establishment of the new path. This is the make-before-break (non-) seamless hard handover type. Another type that might be necessary is called a break-before-make (non-) seamless hard handover. These two types, concerning the transport aspects of the handover process have been clarified in chapter three. In the case there is not sufficient time for the establishment of the new path, the needed handover type is different. In this situation it is possible that the radio link between the MT and the old BTS is...
released before the establishment of the fixed network connection between the new BTS and the network switching point. A hard handover in this situation is referred to as a break-before-make (non-) seamless hard handover.

7.4 Conclusions

This chapter explored the applicability of the developed Handover Generic Model.

The Model has been verified by formulating SDL specifications of the handover application protocol, valid in an example environment. The selected example environment is the public (metropolitan) high traffic environment, according to its importance (i.e., high number of users).

The restrictions that have been made in order to reduce the complexity of the SDL specifications have been described and justified.

The coverage of the Model with respect to all handover scenarios has been studied, by describing the assumptions that have been taken into consideration. Furthermore, the coverage has been studied by the identification of options of the handover aspects that have not been studied.
This report describes the definition of a Generic Model for the handover functionality in UMTS that is suitable for all handover scenarios. In this chapter, conclusions are drawn whether the goal of the project is met (section 8.1). In section 8.2 some recommendations and issues for further study regarding the Handover Generic Model are presented.

8.1 Conclusions

An important functionality, concerning UMTS, is the handover functionality. To efficiently implement this complex functionality, a model is needed that can handle all possible handover scenarios. The development of such a generic model was the goal that had to be achieved for this project.

The analysis of the common features of the handover process in UMTS pointed out that this process depends on several aspects. These aspects are the handover initiation points, handover initiation procedures, bearer types, the UMTS reference configurations and environments, the handover cases, the handover types, and, finally, the radio interfaces that the network has been equipped with.

It is concluded that each handover aspect is relevant during only one particular part of the handover process. Each handover aspect identifies possible options in the performance of the particular part of the handover process. Because of this, each handover scenario can be described by a combination of options regarding these handover aspects.

The aspects and their options have been used to describe the allocation of Functional Entities onto Functional Groups of an example UMTS environment. It is concluded that the precise description of the possible signalling associations between the Functional Entities, and hence between the Functional Groups is valid for each handover scenario.

These signalling relations between the Functional Groups have been characterised by describing the Information Flows. The Information Flows describe the needed interaction between Functional Entities as to support their joint operation. It is concluded that the developed top-level structure of the handover Information Flows is suitable for all handover scenarios.

The developed Handover Generic Model structures the options accompanying each handover aspect, and consequently models all possible handover scenarios. It is concluded that the Model reduces 660 different handover scenarios to 27 modules with which all these scenarios can be performed.

The coverage of the Model has been studied, by formulating SDL specifications of the Functional Groups of the example environment. These SDL specifications are used to simulate all identified handovers. It is concluded that the Model can handle all 660 possible handover scenarios.
8.2 Recommendations and future work

Regarding the restrictions of the SDL specifications

- Three handover cases can occur that have not been specified: intra BTS handover, inter LE handover, and inter environment handover. In a real UMTS these handover cases can occur. Therefore, they have to be specified. In the case of intra BTS handover, this involves the analysis of the radio interfaces. In the case of inter LE/inter environment handover, this involves the analysis of the transfer of control point functionality.

- The network topology of the specified UMTS environment is a tree topology without interconnections between Functional Groups. In future UMTS other topologies and possible interconnected Functional Groups might be needed.

Regarding the assumptions with respect to the handover aspects

- It has been assumed that the radio interfaces do not impact the application layer. With respect to the second generation radio interfaces, this is merely one of the migration options. Another option is that the complete protocol stacks of these radio interfaces are re-used. In that case the Radio Access System must perform the interworking between the UMTS protocol stack and the stack of the radio interfaces.

- All handover scenarios studied in this report are handovers within one security domain. In a real UMTS, handovers can occur between security domains. This requires handover security entities, that have not been studied in this report.

Regarding the coverage of the Handover Generic Model

- The Handover Generic Model only supports backward handover. Another way to perform the initiation of a handover is called forward handover. These handovers might be required, e.g. if a radio interface is used that does not support a backward control of the handover process.

- With respect to the handover types it has been assumed that there is sufficient time for the establishment of the new path. Situations can occur that connections are lost abruptly. In these situations, a handover type is needed with which the call can be recovered. This hard handover type is called a break-before-make handover.
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MESSAGE SEQUENCE CHART (MSC)
Appendix A: FORMULATED SDL SPECIFICATIONS

The feasibility of the Handover Generic Model has been studied by formulating SDL specifications of the Functional Groups of the example environment. These specifications have been placed in this appendix. The meaning of the used SDL symbols can be found in [Z.100] and will not be explained here.

SDL Overview

The structure of the developed SDL specifications of the public (metropolitan) high traffic environment of UMTS is depicted in the following overview (see Figure A-1).

The Figure illustrates that the UMTS users (USERS block) are connected to the B-ISDN Core Network (B-ISDN block) via the Radio Access System (RAS block).

The USERS block consists of one user, and therefore one Mobile Terminal (MT).

The RAS block consists of four BTS sub-blocks and two CSS-level sub-blocks. The CSS-level sub-block is divided into a MSCP(Access) part and a CSS part.

The B-ISDN block consists of one LE-level that is divided into a MSCP(Core) part and a LE part.

This structure is according to the UMTS Reference configurations, as discussed in chapter 3 of this report (Figure 3.4 and Figure 3.5). The sub-blocks and their parts...
can be seen as Functional Groups. The Functional Entities can be allocated onto these Functional Groups, as discussed in chapter 5 of this report. Therefore the Functional Groups are interpreted as processes (not shown in the Figure).

The SDL specifications of the UMTS system are shown according to the hierarchy discussed in chapter 7 (system, block, process, and procedure view).

**System view**

![System view UMTS Public (Metropolitan) High Traffic Environment](image)

*Figure A-2: System view UMTS Public (Metropolitan) High Traffic Environment*
Appendix A Formulated SDL specifications

Figure A-3: UMTS Signal definitions
Development of a generic model for handover in UMTS

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Figure A-4: Signal-lists UMTS system and RAS block
Figure A-5: Signal-lists block types CSS level and LE level

```
/ * Block Type CSSlevel Signallists */
SIGNALLIST MSCP_CSS =
  HO_INIT REQreq.conf,SHRNreq.ind;
SIGNALLIST BTS_CSS =
  CONNECTreq.ind,SHRNresp.conf;
SIGNALLIST BTS_MSCP =
  CONNECTreq.ind,SHRNresp_conf;
SIGNALLIST CSS_MSCP =
  HO_INIT REQreq.conf,SHRNresp.conf;
SIGNALLIST CSS_BTS =
  HO_INIT REQreq.ind,SHRNresp_ind;
SIGNALLIST Access_Core =
  HO_CTRLreq.ind;
SIGNALLIST Core_Access =
  HO_CTRLresp.conf;
SIGNALLIST CSS_LE =
  CONNECTresp.conf,RELEASEresp.conf;
SIGNALLIST LE_CSS =
  CONNECTreq.ind,RELEASEreq.ind;
SIGNALLIST LE_MSCP =
  ADD_CONNreq.conf,DROP_CONNreq.conf,SET_BRIDGEreq.conf,SWITCH_CONNreq.conf,
  RELEASE_CONNreq.conf,CONNECTreq.ind,RELEASEreq.ind;
SIGNALLIST MSCP_LE =
  ADD_CONNreq.ind,DROP_CONNreq.ind,SET_BRIDGEreq.ind,SWITCH_CONNreq.ind,
  RELEASE_BRIDGEreq.ind,CONNECTreq.ind,RELEASEreq.ind;
```

```
/ * Block Type LElevel Signallists */
SIGNALLIST MSCP_LE =
  ADD_CONNreq.conf,DROP_CONNreq.conf,SET_BRIDGEreq.conf,SWITCH_CONNreq.conf,
  RELEASE_CONNreq.conf,CONNECTreq.ind,RELEASEreq.ind;
SIGNALLIST BTS_LE =
  HO_INIT REQreq.ind,SHRNreq.ind;
SIGNALLIST CSS_LE =
  CONNECTreq.ind,SHRNresp_conf;
SIGNALLIST LE_MSCP =
  ADD_CONNreq.conf,DROP_CONNreq.conf,SET_BRIDGEreq.conf,SWITCH_CONNreq.conf,
  RELEASE_CONNreq.conf,CONNECTreq.ind,RELEASEreq.ind;
SIGNALLIST MSCP_BTS =
  ADD_CONNreq.conf,DROP_CONNreq.conf,SET_BRIDGEreq.conf,SWITCH_CONNreq.conf,
  RELEASE_CONNreq.conf,CONNECTreq.ind,RELEASEreq.ind;
```

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Block view

Users

Figure A-6: Block view UMTS users
Figure A-7: Block type Mobile Terminal (MT)
Development of a generic model for handover in UMTS

RAS

Figure A-8: Block view Radio Access System (RAS)

Block Types

Figure A-9: block type Base Transceiver Station (BTS)
Figure A-10: Block type Cell Site Switch (CSS) level

Figure A-11: Block type CSS
Development of a generic model for handover in UMTS

Figure A-12: Block type Mobile Service Control Point (MSCP) (Access)

B-ISDN

Figure A-13: Block view B-ISDN
Block Types

Figure A-14: Block type Local Exchange (LE) level

Figure A-15: Block type LE
Figure A-16: Block type MSCP(Core)

Process View

Figure A-17: Bearer Control (BC) process
Figure A-18: BC process (continuation)

Figure A-19: Combining and Multicasting Control (CMC) process
Development of a generic model for handover in UMTS

Figure A-20: Handover Control (HC) process

Figure A-21: Handover Decision (HD) process
Figure A-22: HD process (continuation)
Development of a generic model for handover in UMTS

Figure A-23: Handover Initiation (HI) process
Process Type HI

Figure A-24: HI process (continuation)
Figure A-25: HI process (continuation)
Figure A-26: HandOver Control (HOC) process

Figure A-27: Handover User Profile - Network (HUPN) process
Development of a generic model for handover in UMTS

Figure A-28: Handover User Profile - User (HUPU) process

Figure A-29: MEasurement Function (MEF) process
Appendix A Formulated SDL specifications

Figure A-30: Radio Bearer Control (RBC) process

Figure A-31: Switching and Bridging Control (SBC) process

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Development of a generic model for handover in UMTS

**Process Type SHRN**

![Diagram](image)

Figure A-32: Special Handover Request - Network (SHRN) process

**Process Type SHRU**

![Diagram](image)

Figure A-33: Special Handover Request - User (SHRU) process

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Appendix A Formulated SDL specifications

Figure A-34: Target Cells and Connections - Network (TCCN) process

Figure A-35: Target Cells and Connections - User (TCCU) process
Development of a generic model for handover in UMTS

Procedure View

HD process

![Diagram of HD process]

Figure A-36: Procedure HO calculation

HL process

![Diagram of HL process]

Figure A-37: Procedure HLslave
Appendix A Formulated SDL specifications

**Figure A-38: Procedure HL_HandoverDecision**

**HOC process**

**Figure A-39: Procedure NonSeamHardHO**
Development of a generic model for handover in UMTS

Figure A-40: Procedure SeamHardHO

Figure A-41: Procedure SoftHO
Appendix B: MESSAGE SEQUENCE CHARTS

As examples of the message flows between entities, needed during particular handover scenarios, three Message Sequence Charts (MSCs) are shown. These MSCs are constructed using the simulator tool of SDT.

Figure B-1: The HI in both MT and network, SHRN, inter BTS, soft handover scenario
Figure B-2: The Hi in MT, SHRU, inner BTS, non-seamless handover scenario
Figure B.3: The HI in BTR's Mobile Assisted Inter CSS seamless handover scenario