

UMTS UTRAN Signaling

Understand and Analyze
UMTS UTRAN Message Flows
and Procedures

Ralf Kreher

Tektronix Monitor & Protocol Test, Berlin

Juergen Placht

Tektronix Monitor & Protocol Test, Munich

Torsten Ruedebusch

Tektronix Monitor & Protocol Test, Berlin

Network Diagnostics



Tektronix

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ii Preface

UMTS is the most complex technology in 150 years of communication industry. Implementing and deploying communication networks based on UMTS results in exciting and fascinating new services and applications. However at the same time it generates enormous technical challenges. Interoperability, roaming or QoS awareness between multi operators and multi technology network infrastructures are just a few of the problems, which need to be met. In today's early deployments of UMTS networks five main categories of problems can be differentiated:

- (1) Network Element Instability
- (2) Network Element Interworking
- (3) Multi Vendor Interworking (MVI)
- (4) Configuration Faults
- (5) Network Planning Faults

To successfully trial, deploy, operate or troubleshoot such infrastructures and applications, it is vital to understand and analyze the message flows associated with UMTS. This book gives a deep insight into the secrets and depths of UMTS signaling on the wireline interfaces. It

- Displays documented reference scenarios for different procedures
- Explains the procedures at different interfaces
- Improves protocol knowledge
- Analyzes specific protocol messages
- Helps to reduce time and effort to detect and analyze problems and
- Explains how to locate problems in the network.

It is assumed, that the reader of this book is already familiar with UMTS technology at a fairly detailed level. It is directed to UMTS experts, who need to analyze UMTS signaling procedures at the most detailed level. This is why only an introductory overview section discusses the UMTS Network architecture, the objectives and functions of the different interfaces and the various UMTS protocols. Then the book leads right into the main part - the analysis of all main signaling processes in a UMTS networks, so called UMTS scenarios. All main procedures -from Node B Setup to Hard Handover- are described and explained comprehensively.

All signaling sequences are based upon UMTS traces from various UMTS networks (trial and commercial networks) around the world. With this book the reader has access to the first universal UMTS protocol sequence reference, which allows to quickly differentiate valid from invalid call control procedures. In addition all main signaling stages are being explained, many of which had been left unclear in the standards so far. They now can be analyzed based on protocol traces from actual implementations. At the same time - other than in the standards - dealing with unnecessary bits and pieces is avoided, allowing the user of the book to focus on the essentials of each signaling process.

With this book Tektronix launches a new generation of knowledgeware products, providing highly specialized knowledge from experts for experts.

The combination of a network of UMTS experts around the world from many different companies with Tektronix' many years of experience in protocol analysis have resulted in this unique book, compendium and reference. I hope it will prove helpful for the successful implementation and deployment of UMTS.

Othmar Kyas
Monitoring and Protocol Test
Tektronix Inc.

If you have any kind of feedback or questions feel free to send us an email to **umts-signaling@tektronix.com**

Every entry that spots a technical mistake in this book first will be rewarded with either the next edition or with the upcoming CD ROM version.

For help with acronyms or abbreviations, refer to the glossary at the end of this guide.

iv About the Authors

Ralf Kreher

*Manager for Customer Training
Mobile Protocol Test
Tektronix, Inc.*

Ralf Kreher leads the Customer Training Department for Tektronix' Mobile Protocol Test business (MPT). He is responsible for the world-class seminar portfolio for mobile technologies and measurement products.

Before joining Tektronix, Kreher held a trainer assignment for switching equipment at Teles AG.

Kreher holds a Communication Engineering Degree of the Technical College Deutsche Telekom Leipzig. He currently resides in Germany.

Juergen Placht

*Senior Application Engineer
Mobile Protocol Test
Tektronix, Inc.*

Juergen Placht supports sales and customers worldwide in all technical aspects of mobile network protocol test. He is a well-known technology expert at network vendors and operators.

Before joining Tektronix, Placht held several R&D, sales and marketing assignments at Tekelec and Siemens.

Placht holds an Electrical Engineering Degree. He currently resides in Germany.

Torsten Ruedebusch

*Head of Knowledgeware and Training Department
Mobile Protocol Test
Tektronix, Inc.*

Torsten Ruedebusch is the head of the Knowledgeware and Training Department for Tektronix' Mobile Protocol Test business (MPT). He is responsible for providing leading edge technology and product seminars and the creation of knowledgeware products, created from the extensive Tektronix' expertise.

Before joining Tektronix, Ruedebusch held an application engineer assignment at Siemens CTE.

Ruedebusch holds a Communication Engineering Degree of the Technical College Deutsche Telekom Berlin. He currently resides in Germany.

1 UMTS Basics

The mobile communications industry is renowned for its technical innovation, rapid growth and tantalizing promises. In contrast to the dramatic downturn in the general communications market, the mobile sector has continued to grow and evolve.

The technologies used to provide wireless voice and data services to subscribers, such as Time Division Multiple Access (TDMA), Universal Mobile Telecommunications Systems (UMTS) and Code Division Multiple Access (CDMA), continue to grow in their complexity. This complexity continues to impart a time-consuming hurdle to overcome when moving from 2G to 2.5G and to third-generation (3G) networks.

GSM (Global System for Mobile Communication) is the most widely installed wireless technology in the world. Some estimates put GSM market share at up to 80%. Long dominant in Europe, GSM is now gaining a foothold in Brazil and is expanding its penetration in the North American market.

One reason for this trend is the emergence of reliable, profitable 2.5G GPRS elements and services. Adding a 2.5G layer to the existing GSM foundation has been a cost-effective solution to current barriers while still bringing desired data services to market. Now, those same operators and manufacturers are getting ready to come to market with 3G UMTS services, the latest of which is UMTS Release 4 (R4). This transition brings new opportunities and new testing challenges, both in terms of revenue potential and addressing interoperability issues to ensure QoS.

With 3G mobile networks, the revolution of mobile communication has just begun. 4G and 5G networks will make the network transparent to the user's applications. In addition to horizontal handovers (for example between Node Bs), handovers will occur vertically between applications and the terrestrial UTRAN (UMTS Terrestrial Radio Access) will be extended by a satellite-based RAN (Radio Access Network), ensuring global coverage.

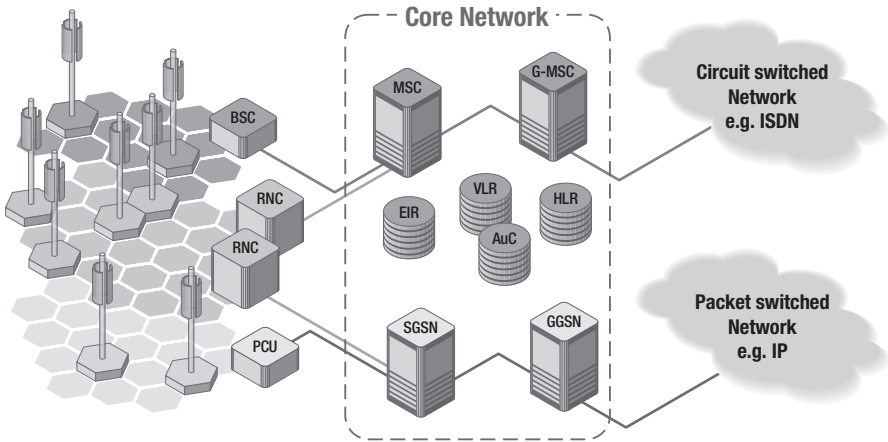


Figure 1 Component Overview of a UMTS Network

Today, there is no doubt anymore; UMTS is real.

Every day the number of tests and trials in different parts of the world increases rapidly. In some regions we already find active UMTS networks. Therefore, network operators

and equipment suppliers are desperate to understand how to handle and analyze UMTS signaling procedures in order to get the network into operation, detect errors, and troubleshoot faults.

Those experienced with GSM will recognize many similarities with UMTS, especially in Non-Access Stratum or NAS-messaging. However, in the lower layers within the UTRAN, UMTS introduces a set of new protocols, which deserve close understanding and attention.

The philosophy of UMTS is to separate the user plane from the control plane, the radio network from the transport network, the access network from the core network, and the access stratum from the non-access stratum.

The first part of this book is a refresher on UMTS basics, the second part continues with in-depth message flow scenarios of all kinds.

1.2 Network Architecture

UMTS maintains a strict separation between the radio subsystem and the network subsystem, allowing the network subsystem to be reused with other radio access technology. The core network is adopted from GSM and consists of two user traffic-dependent domains and several commonly used entities.

Traffic-dependent domains correspond to the GSM or GPRS core networks and handle:

- Circuit switched type traffic in the CS Domain
- Packet switched type traffic in the PS Domain

Both traffic-dependent domains use the functions of the remaining entities – the Home Location Register (HLR) together with the Authentication Center (AC), or the Equipment Identity Register (EIR) – for subscriber management, mobile station roaming and identification, and handling different services. Thus the HLR contains GSM, GPRS, and UMTS subscriber information.

Two domains handle their traffic types at the same time for both the GSM and the UMTS access networks. The CS domain handles all circuit switched type of traffic for the GSM as well as for the UMTS access network; similarly, the PS domain takes care of all packet switched traffic in both access networks.

1.2.1 GSM

The second generation of PLMN is represented by a GSM network consisting of Network Switching Subsystem (NSS) and a Base Station System (BSS).

The first evolution step (2.5G) is a GPRS PLMN connected to a GSM PLMN for packet-oriented transmission.

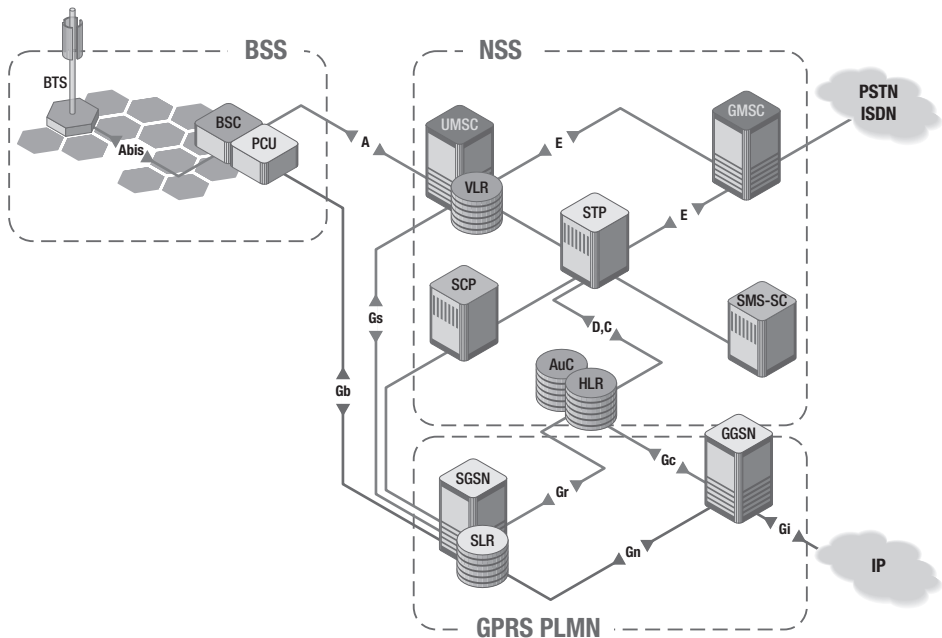


Figure 5 GSM Network Architecture

The main element in the NSS is the Mobile Switching Center (MSC), which contains the Visitor Location Register (VLR). The MSC represents the edge towards the BSS and on the other side as Gateway MSC (GMSC), the connection point to all external networks, such as the Public Switched Telephone Network or ISDN. GSM is a circuit switched network, which means that there are two different types of physical links to transport control information (signaling) and traffic data (circuit). The signaling links are connected to Signaling Transfer Points (STP) for centralized routing whereas circuits are connected to special switching equipment.

HLR	Home Location Register	SGSN	Serving GPRS Support Node
AuC	Authentication Center	SLR	SGSN Location Register
SCP	Service Control Point	GGSN	Gateway GPRS Support Node
SMS-SC	Short Message Service Center	CSE	CAMEL Service Entity (Customized Application for Mobile network Enhanced Logic)

The most important entity in BSS is the Base Station Controller, which, along with the Packet Control Unit (PCU), serves as the interface with the GPRS PLMN. Several Base Stations (BTS) can be connected to the BSC.

1.2.2 UMTS Release 99

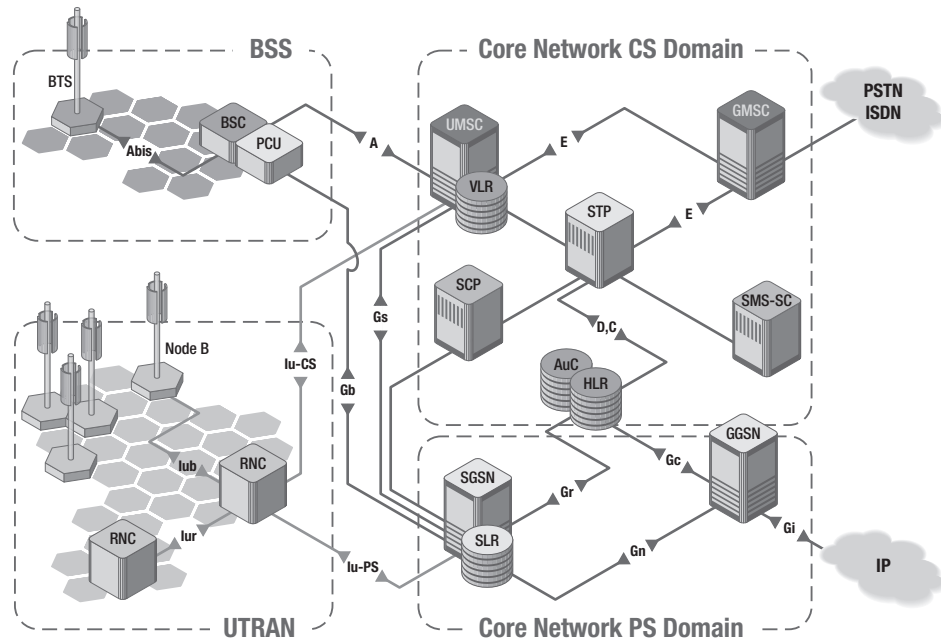


Figure 6 UMTS Rel. 99 Network Architecture

To implement UMTS means to set up a UMTS Terrestrial Radio Access Network (UTRAN), which is connected to a circuit switched core network (GSM with UMSC/VLR) and to a packet switched core network (GPRS with SGSN/SLR). The interfaces are named Iu whereas Iu-CS goes to the UMSC and Iu-PS goes to the SGSN.

The corresponding edge within UTRAN is the Radio Network Controller (RNC). Other than in the BSS the RNCs are connected with each other via the Iur interface.

1.5.14 UMTS Network Transactions

The following figure shows the order of the necessary transactions of a connection. It further indicates the interworking of pure signaling exchange and Radio Bearer procedures.

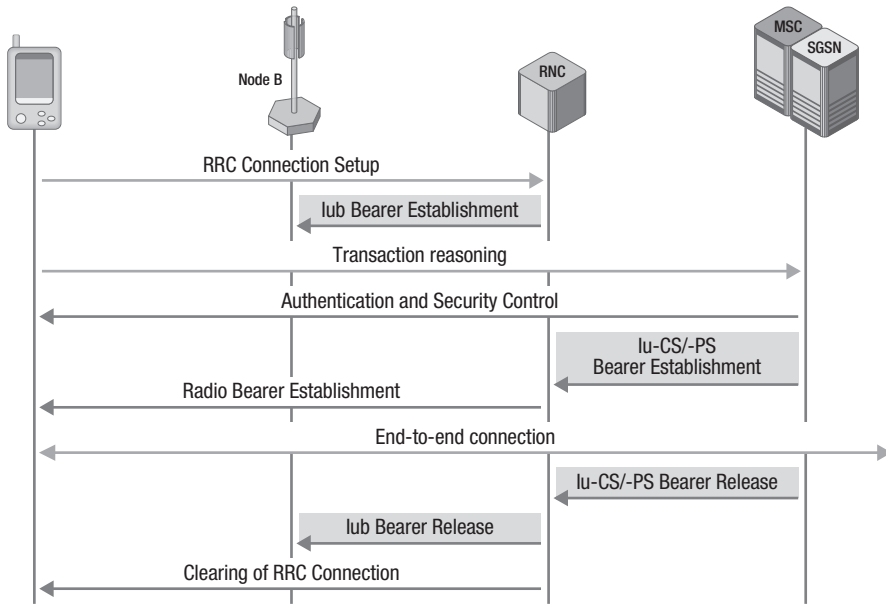


Figure 25 Network Transitions

The procedures running between UE, Node B, and RNC will exchange Access-Stratum (AS) messages whereas procedures going through to the core network, MSC and SGSN, will exchange Non-Access Stratum (NAS) messages.

2.1 Iub - Node B Setup

A Node B Setup will be performed if you have installed a new Node B, made changes in configuration, or reset a system (for example, for installation of a new software version). To “announce” these changes to the network, the Node B initiates the Setup procedure.

2.1.1 Overview

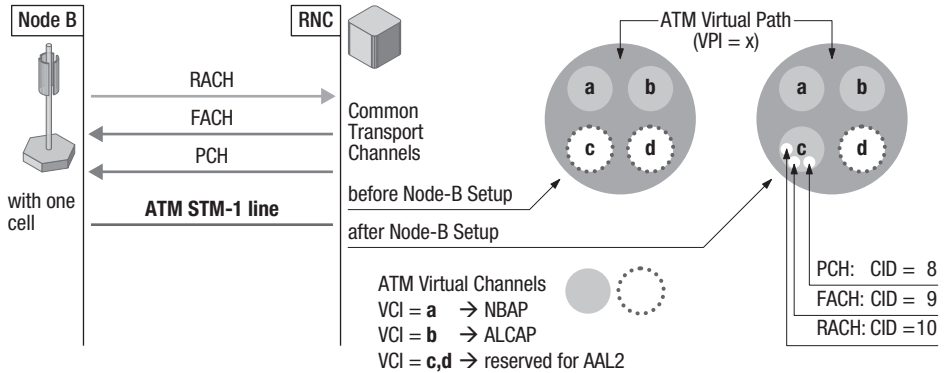


Figure 95 Node B Setup Overview

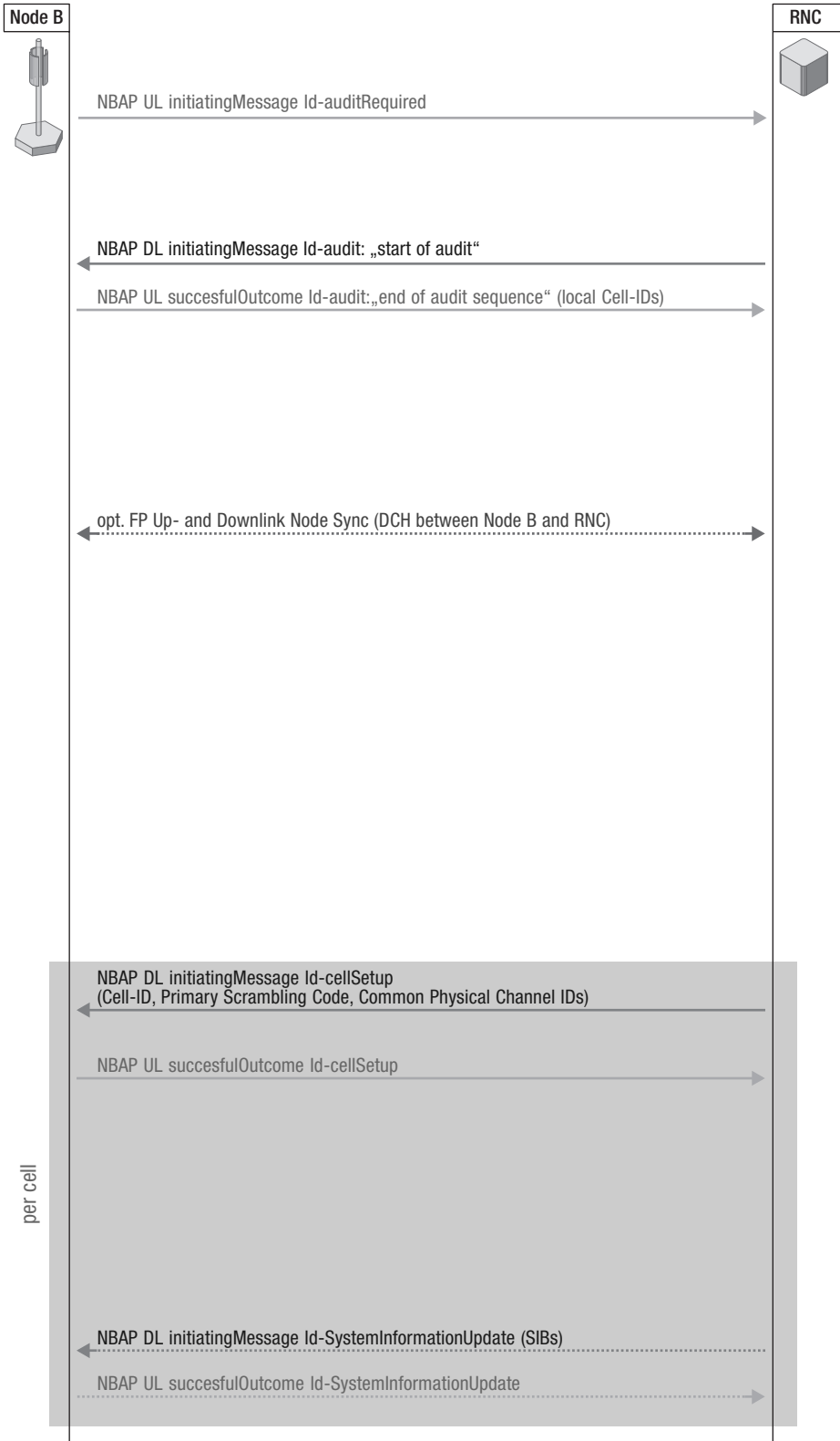
If a Node B is set up against a Radio Network Controller (RNC), this setup will happen in three steps.

- Step 1: The Node B requests to be audited by the RNC. During the audit, Node B informs the RNC of how many (just one or more) cells belong to the Node B and which local cell identifiers they have.
- Step 2: For each cell, the RNC performs a Cell Setup. During the Cell Setup, the physical (radio interface) channels are parameterized. These channels are mandatory in case of a User Equipment (UE) initial access. In other words: if these channels are not available it is impossible for the UE after it is switched on to get access to the network via the radio interface.
- Step 3: The common transport channels Paging Channel (PCH), Forward Access Channel (FACH), and Random Access Channel (RACH) are set up and optionally parameterized in each cell of the new Node B. On the Iub interface these common transport channels are carried by AAL2 connections on ATM lines. ATM/AAL2 header values (VPI/VCI/CID) are important, because without knowing them it is impossible to monitor signaling and data transport on PCH, RACH, and FACH. If these channels are not monitored some of the most important messages for call setup and mobility management procedures, such as Paging messages and `rrcConnectionSetup`, will be missed in call traces. Once the AAL2 connection for a common transport channel is installed during Node B setup it will not be released until this Node B is taken out of service or reset.

2.1.2 Message Flow

The Node B Setup Procedure is executed when a new Node B is taken into service or after reset.

With an `auditRequired` message, the Node B requests an audit sequence by the RNC. One audit sequence consists of one or more audit procedures (our example consists of only



one audit procedure). An NBAP Class 2 Elementary procedure transmits an auditRequired procedure code without requiring a response (connectionless). Hence, longTransactionID has no meaning and the value is 0.

NBAP UL initiatingMessage Id-auditRequired (longTransActionID=**a**)

The Audit procedure belongs to NBAP Class 1 Elementary Procedures and requires response (connection-oriented). Both messages, Initiating Message and Successful Outcome, are linked with the same longTransactionID value **b**.

NBAP DL initiatingMessage Id-audit (longTransActionID=**b**)

NBAP UL successfulOutcome Id-audit (longTransActionID=**b**, id-local Cell ID's=**{0,1,2,...}**)

The Node B sends a SuccessfulOutcome Response for the audit procedure to the RNC. Included is the information how many cells belong to the Node B. A local Cell-ID is assigned to each of its cells. In addition, Node B reports to the RNC the power consumption law values for common and dedicated channels for all cells, so that, from then on, the RNC is able to control the power resources of each cell, one of the most critical parameters for UMTS air interface operation.

FP Up- and Downlink Node Synchronization – alignment of Framing Protocol frame numbers and timers on RNC and Node B side.

Each cell executes the following steps:

With the CellSetup message, the RNC assigns a Cell-ID (id-C-ID) to each single local Cell ID. Other important parameters inside the cell setup message are:

- Primary Scrambling Code
- Common Physical Channel IDs of:
 - Primary Synchronization Channel (P-SCH)
 - Secondary Synchronization Channel (S-SCH)
 - Primary Common Pilot Channel (CPICH)
 - Common Control Physical Channel (CCPCH).

The common physical channels are necessary to ensure successful initial UE access.

NBAP DL initiatingMessage Id-CellSetup (longTransActionID=**c**, Id-local Cell ID=**{0}**, id-C-ID=**e**)

Node B confirms the transmission of parameters with:

NBAP UL successfulOutcome Id-CellSetup (longTransActionID=**c**)

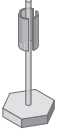
Optional procedure:

An optional System Information Update may either follow the Cell Setup or the end of the whole Node B Setup procedure. In this System Information Update, several System Information Blocks (SIBs) are transmitted. These SIBs contain parameters like timers and counters for changing RRC states and UMTS Registration Area (URA) Identity. A Master Information Block (MIB) contains information about which of the many different SIBs are provided for a particular Cell-ID.

NBAP DL initiatingMessage Id-SystemInformationUpdate (longTransActionID=**d**, id-C-ID=**e**, SIBs)

NBAP UL successfulOutcome Id-SystemInformationUpdate (longTransActionID=**d**)

Node B



RNC



NBAP DL initiatingMessage Id-commonTransportChannelSetup
(Cell-ID, CTrCh-ID + PCH TFS)

NBAP UL succesfulOutcome Id-commonTransportChannelSetup (CTrCH-ID, bind-ID=**h**)

ALCAP DL ERQ (Path-ID, Ch-ID, SUGR=**h**)

ALCAP UL ECF



After a successful Cell Setup, RNC starts the Common Transport Channel (CTrCh) Setup for each cell. The RNC sends a Common Transport Channel Setup request to the Node B that serves the cell. The cell is registered on the RNC side with its Cell ID and a list of parameters for the Transport Channel (in this case: PCH). The request includes radio related items such as the Common Transport Channel ID (CTrCH-ID) and the Transport Format Set (TFS) of the CTrCH.

In the case of Common Transport Channel Setup for the PCH, the message also contains the parameters for the appropriate paging indication channel (PICH).

NBAP DL initiatingMessage Id-commonTransportChannelSetup (longTransActionID=**f**, id-C-ID=**e**, id-PCH-ParametersItem-CTCH-SetupRqstFDD, commonTransportChannelID=**g**, PICH Parameters)

NBAP UL successfulOutcome Id-commonTransportChannelSetup (longTransActionID=**f**, commonTransportChannelID=**g**, bindingID=**h**)

The Node B answers with a Successful Outcome message including the same procedure code “Common Transport Channel Setup” and the same CTrCH-ID. In addition, Node B provides a binding ID (bind-ID). This binding-ID connects the NBAP signaling with the following AAL2L3 procedure. The value of the binding ID will be used as Served User Generated Reference (SUGR) in the AAL2L3 Establish Request (ERQ) message.

In some systems, bind-ID and SUGR are decoded in different formats since the NBAP specification defines a binding ID as a 4-octet string only; in contrast, AAL2L3 says the coding of SUGR depends on implementation. Therefore, the binding ID could be shown in hexadecimal format while the SUGR is decoded as a decimal number – but the value remains the same. For example: **01 80** (hex) = **384** (dec)

ALCAP DL ERQ

(Originating Signal. Ass. ID=**i**, AAL2 Path=**k**, AAL2 Channel id=**l**, served user gen reference=**h**)

ALCAP UL ECF (Originating Signal. Ass. ID=**m**, Destination Sign. Assoc. ID=**i**)

If requested by the NBAP, the ALCAP or AAL2L3 sets up a Switched Virtual AAL2 Connection (SVC). The set up of an AAL2 connection is required, because this connection will be the physical layer for the common transport channel on the Iub interface that will be installed later in this process.

The AAL2 virtual connection is uniquely identified by:

- ATM Virtual Path Identifier (VPI)
- ATM Virtual Channel Identifier (VCI)
- AAL2 Connection Identifier (CID)

The AAL2L3 Establish Request (ERQ) sent by the RNC already includes two important parameters:

- Path-ID
- Channel-ID (Ch-ID)

However, the **Path-ID** in the ERQ message is **not** the same as the **VPI**! The Path-ID is a mapping of VPI and VCI.

While the Channel-ID of the ERQ message will be used as a value for the AAL2 Connection ID (CID), the VPI/VCI combination of the ATM header can be found in a configura-

2.10 Iub-Iu - Location Update

2.10.1 Overview

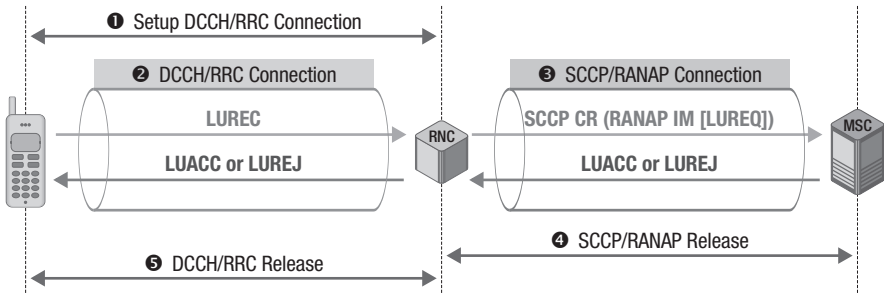
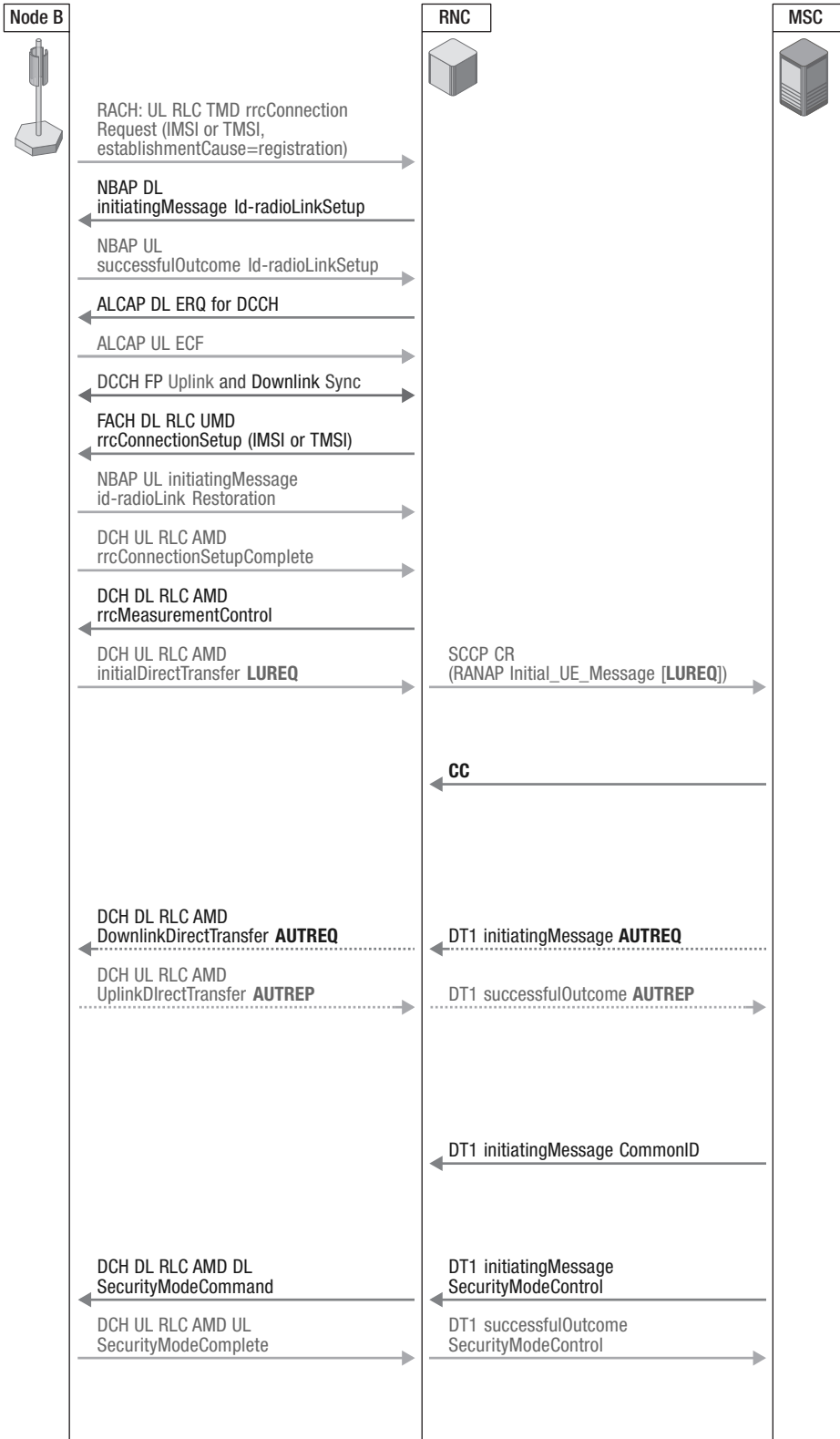


Figure 104 LUP Iub-Iu Overview

Now we will have a more detailed look at the signaling procedures on the Iu interfaces. To understand this it is also necessary to understand the procedures running on Iub – as described in the call flow examples previously (2.1–2.9). However, the focus will be on those Iub messages that trigger Iu activities.

The start is the already well-known Location Update (LUP) procedure.

- Step 1: Set up the dedicated control channel (DCCH) for the RRC connection on the Iub interface.
- Step 2: MM/CC/SM (Mobility Management/Call Control/Session Management) messages are transparently forwarded to the RNC on behalf of the RRC direct transfer messages; in this case the Location Update Request (LUREQ) message.
- Step 3: The reception of the LUREQ message triggers the setup of a SCCP/RANAP connection on the Iu-CS interface towards MSC/VLR. The LUREQ is embedded in a RANAP Initial Message, which is also embedded in a SCCP Connection Request. The answer can be either Location Update Accept (LUACC) or Location Update Reject (LUREJ).
- Step 4: After sending the answer message, the SCCP/RANAP connection on Iu-CS is released.
- Step 5: Triggered by the release messages from the Iu-CS the RRC connection and its DCCH are also released.



2.10.2 Message Flow

Iu-LUP:

First the DCCH on Iub interface is set up.

After the RRC connection is established, MM/CC/SM messages can be exchanged embedded in RRC Direct Transfer messages. The mobile sends a Location Update Request.

When the RNC receives the NAS (Non Access Stratum) message, it starts to set up the SCCP connection on the Iu-CS interface on behalf of the SCCP Connection Request message. This CR message includes a RANAP Initial_UE_Message that carries the embedded NAS message Location Update Request (LUREQ). The Source Local Reference Number in the CR message identifies the calling party of this SCCP connection. It will be used as the destination local reference number in all messages sent by the other side (called party) of the SCCP connection; in this case the other party is the MSC/VLR:

SCCP CR (source local reference=**a**, *RANAP Initial_UE_Message*, NAS message=**LUREQ**)

When the RNC receives the SCCP Connection Confirm message from the MSC, then the SCCP connection is established successfully:

SCCP CC (source local reference=**b**, destination local reference=**a**)

For exchange of user data, SCCP provides Data Format 1 (DT1) messages in case of a SCCP Class 2 connection like this. In these DT1 messages, once again RANAP messages and NAS messages (MM/CC/SM) are embedded:

SCCP DT1 (destination local reference=**a**, *RANAP initiatingMessage*, NASmessage=**AUTREQ**)

SCCP DT1 (destination local reference=**b**, *RANAP successfulOutcome*, NASmessage=**AUTREP**)

The Authentication procedure shown in this call flow example is optional.

With the RANAP Initiating Message that contains the Common ID procedure code, the true identity (IMSI) is sent to the RNC so that the RNC can check the stored relation between TMSI and IMSI:

SCCP DT1 (destination local reference=**a**, *RANAP initiatingMessage*, **Common ID**)

With the RANAP Security Mode Control procedure ciphering and/or integrity protection between RNC and UE are activated:

SCCP DT1 (destination local reference=**a**, *RANAP initiatingMessage*, **SecurityModeControl**)

SCCP DT1 (destination local reference=**b**, *RANAP successfulOutcome*, **SecurityModeControl**)