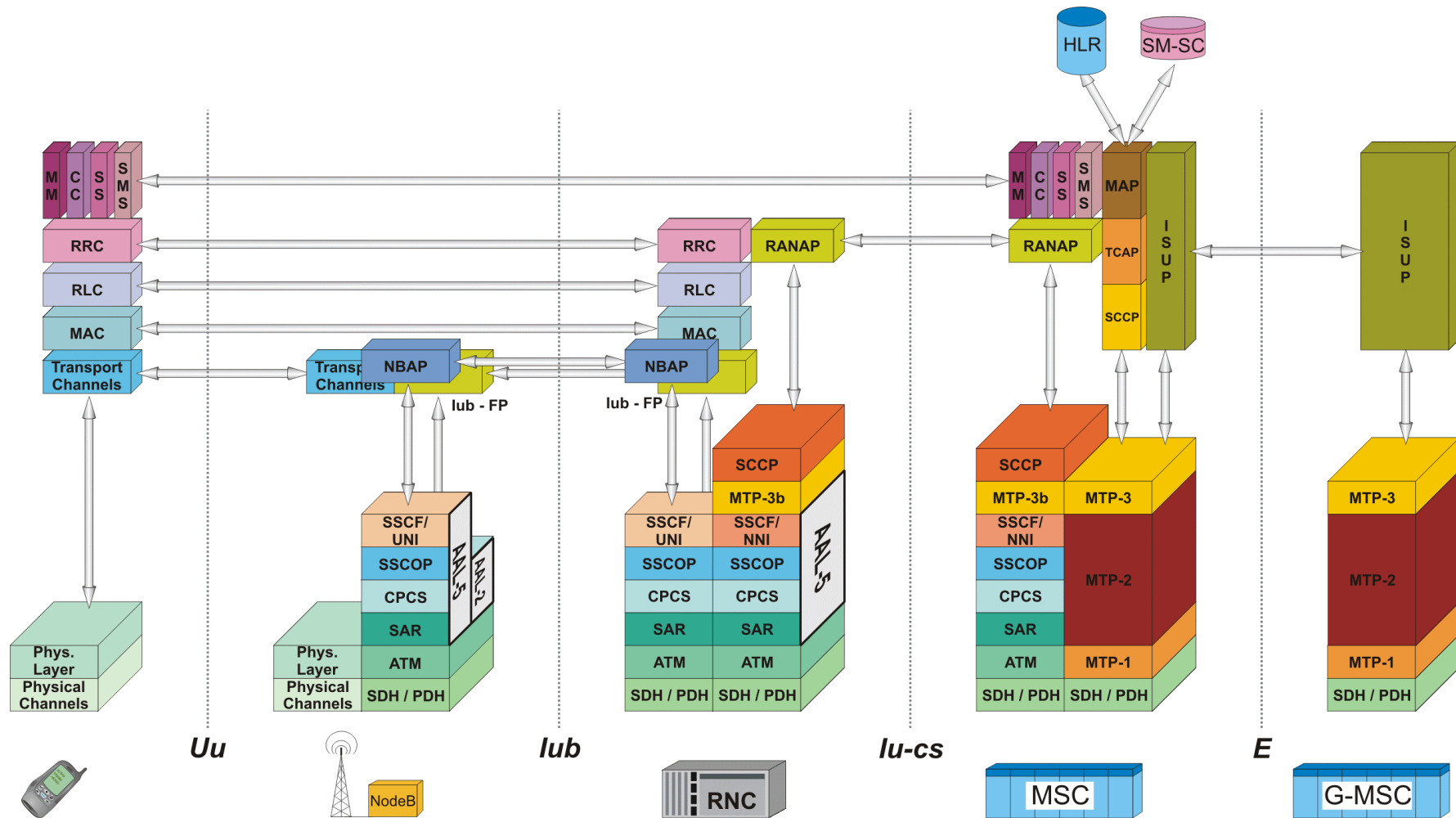


The Circuit-Switched Control Plane



The Circuit-Switched Control Plane

The circuit-switched control plane is used for the exchange of control information which are related to circuit-switched services. In addition, the circuit-switched control plane is used for controlling supplementary services and it can be used for the exchange of short messages.

Access Stratum Protocols

The Access Stratum (AS) protocols are all protocols within the rectangle that is defined by the RRC-protocol (Radio Resource Control) at the upper left corner, the MAC-protocol (Medium Access Control) at the lower left corner and the RANAP-protocol (Radio Access Network Application Part) at the upper right corner.

Non Access Stratum Protocols

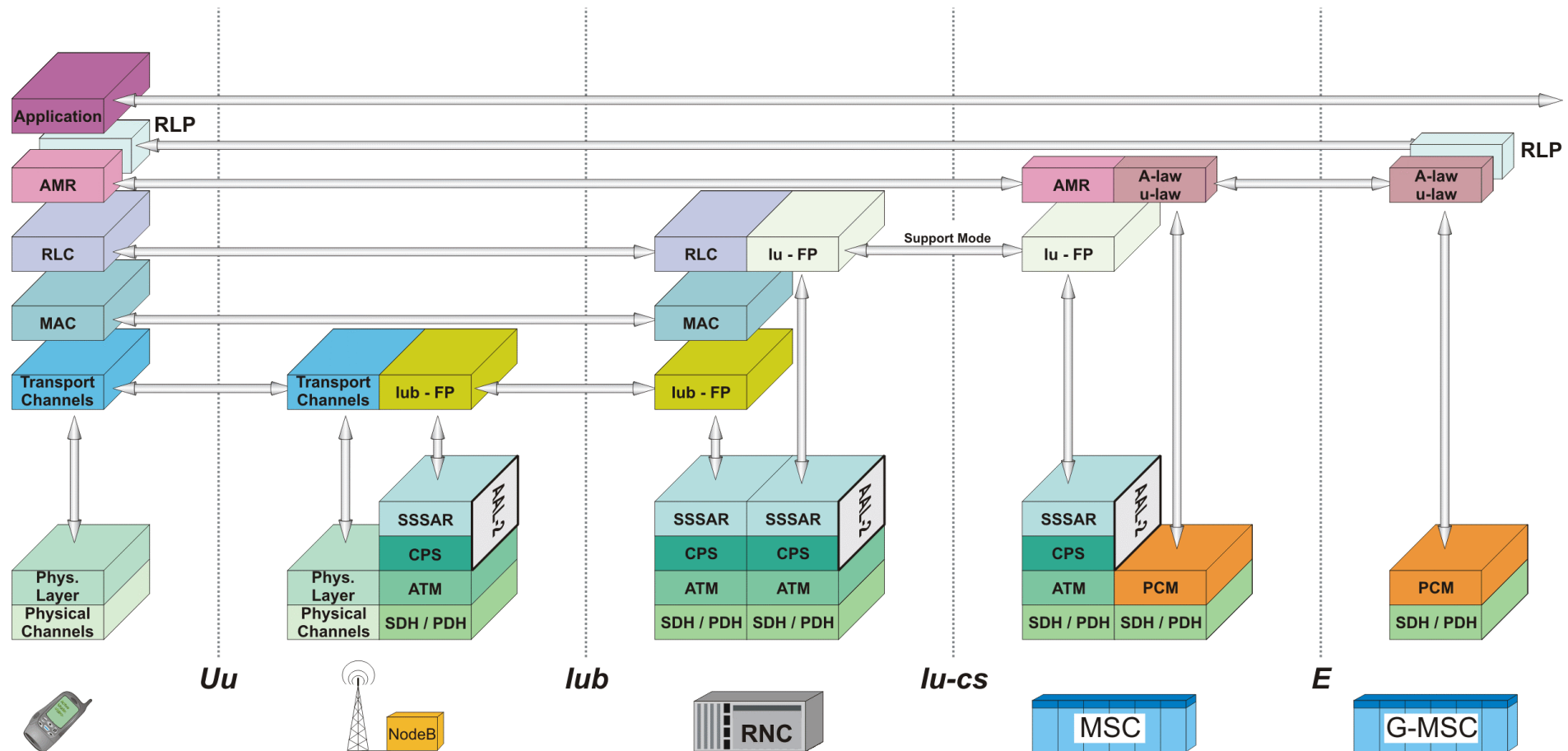
The Non Access Stratum (NAS) protocols could be all the remaining protocols but usually people refer to MM (Mobility Management), SS (Supplementary Services), CC (Call Control) and SMS (Short Message Services) as NAS-protocols within the circuit-switched control plane.

AAL-2 vs. AAL-5

Please note that AAL-5 is used for all control functions on the Iu-CS-interface (\Leftrightarrow RANAP) and the Iub-interface (\Leftrightarrow NBAP). On the other hand, the real-time AAL-2 is used for relaying UE-data and UE-signaling messages (\Leftrightarrow Iub-FP) between NodeB and RNC and for user data on the Iu-CS-interface between RNC and MSC (next page).

[3GTS 25.412]

The Circuit-Switched User Plane



The Circuit-Switched User Plane

The circuit-switched control plane is exclusively used for the exchange of circuit-switched user data. In that respect, user data relates to standard voice transmission or multimedia or streaming applications.

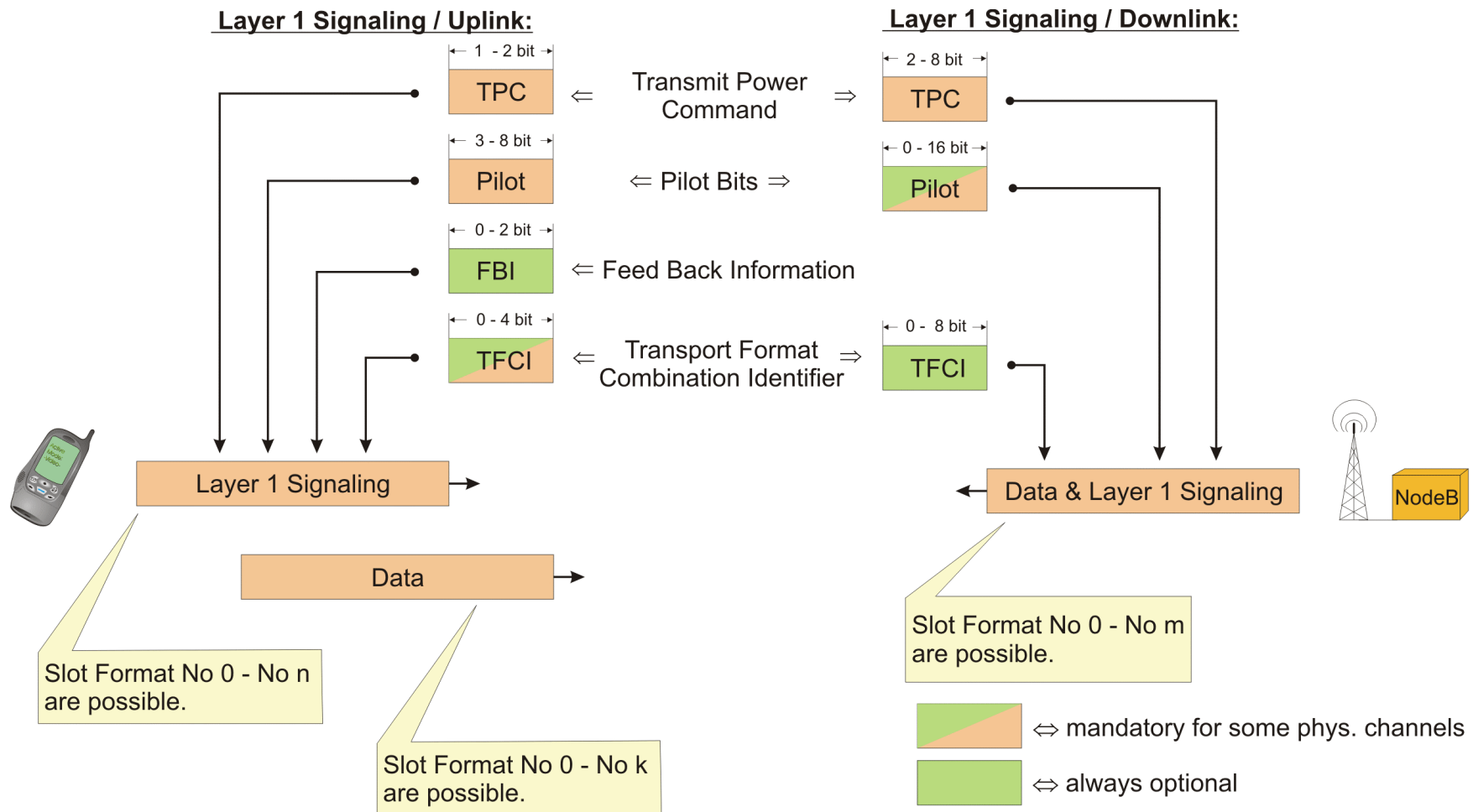
The applications use AMR (Adaptive Multirate Encoding) for speech transmission and / or the RLP (Radio Link Protocol) for circuit-switched data transmission. Please recall that in UMTS multiple data streams can be configured, operated, re-configured and de-configured in parallel and simultaneously.

Please note that the lu-FP is operated in “support Mode” within the circuit-switched user plane while it is operated in “transparent mode” in the packet-switched user plane.

The underlying transport network is using the real-time AAL-2 all the way on the lub-interface and the lu-cs-interface to provide for suitable QoS.

[3GTS 25.414]

Layer 1 Signaling in Data Transferring Physical Channels



Layer 1 Signaling in Data Transferring Physical Channels

On all physical channels that are available for data exchange between the UE and the NodeB there exists the need to exchange layer 1 signaling information between UE and NodeB. Which type of signaling information shall be used and how it is to be interpreted by UE and NodeB is selected by the RRC-layer during the setup of the respective physical channels. Accordingly, these physical channels support different slot formats which are identified through the presence and length of the layer 1 signaling information and through the spreading factor.

The following layer 1 information is defined:

TPC-Field

The TPC-field (Transmit Power Command) is mandatory in uplink and downlink direction. However, the length of the TPC-field is variable and depends on the selected slot format. The TPC-field is used for fast closed loop power control and tells the receiver to either increase or decrease its transmit power.

Pilot Bits

Pilot bits consist of a pre-defined bit sequence to allow the receiver a channel quality estimation. The number of pilot bits per slot is variable in uplink and downlink direction and depends on the slot format as selected by RRC. On S-CCPCH, the presence of pilot bits is optional.

FBI-Field

The FBI-field (FeedBack Information) is optionally used in uplink direction only. The FBI-field is again split into the S-field and the D-field:

- ⇒ The S-field is used to select the primary cell in a soft-handover situation, if the *site selection diversity transmit power control* procedure (SSDT) is used. All non-primary cells shall switch-off their downlink transmission to that mobile station.
- ⇒ The D-field is used to provide phase shift feedback information to the NodeB for both transmit antennas in case of *closed loop mode transmit diversity*.

TFCI-Field

The TFCI-field is used to inform the receiver of a physical channel about the transport formats of the embedded transport channels. In the control part of the PRACH and PCPCH, the presence of the TFCI-field is mandatory / fixed length while on DPDCH, the presence and length of the TFCI-field depends on the slot format as selected by RRC.

[3GTS 25.211 (5.2.1), 3GTS 25.214 (5.2.1.4 / 7)]

Example: Slot Format Definition for DPDCH/U and DPCCH/U

4. Implicit selection of non-compressed format because “compressed format IE” is not present in the RB_SETUP- message. Therefore transmission will occur on 15 slots per radio frame

1. SF = 64 only relates to the minimum spreading factor and therefore the slot format on DPDCH/U. For DPCCH/U there will always be SF = 256

Extract of RB_SETUP-Message

```

2.1.1.1.9 ul-ChannelRequirement
2.1.1.1.9.1 ul-DPCH-Info
2.1.1.1.9.1.1 modeSpecificInfo
2.1.1.1.9.1.1.1 fdd
---1--- 2.1.1.1.9.1.1.1.1 scramblingCodeType
**b24** 2.1.1.1.9.1.1.1.2 scramblingCode
        2.1.1.1.9.1.1.1.3 numberOfDPDCH
----100- 2.1.1.1.9.1.1.1.4 spreadingFactor
-----1 2.1.1.1.9.1.1.1.5 tfci-Existence
    
```

2. The IE “Number of FBI-bits” is not present after the IE “TFCI-Existence”. Accordingly, the related slot format shall contain no FBI-bits.

Extract of 3GTS 25.211 (Table 11 / Slot Format DPCCH/U):

Slot Format #i	Channel Bit Rate (kbps)	Channel Symbol Rate ksp/s	SF	Bits/ Frame	Bits / Slot	N _{pilot}	N _{TPC}	N _{TFCI}	N _{FBI}	Transmitted slots per radio frame
0	15	15	256	150	10	6	2	2	0	15
0A	15	15	256	150	10	5	2	3	0	10-14
0B	15	15	256	150	10	4	2	4	0	8-9
1	15	15	256	150	10	8	2	0	0	8-15
2	15	15	256	150	10	5	2	2	1	15
2A	15	15	256	150	10	4	2	3	1	10-14
2B	15	15	256	150	10	3	2	4	1	8-9
3	15	15	256	150	10	7	2	0	1	8-15
4	15	15	256	150	10	6	2	0	2	8-15
5	15	15	256	150	10	5	1	2	2	15
5A	15	15	256	150	10	4	1	3	2	10-14
5B	15	15	256	150	10	3	1	4	2	8-9

3. TFCI shall be present.

Example: Slot Format Definition for DPDCH/U and DPCCH/U

The graphics pages illustrates an extract of an RB_SETUP-message. This message contains, among other things, the IE “Uplink DPCH-Info” which informs the UE which slot format it shall apply on the respective DPDCH/U and DPCCH/U.

The green field illustrates an extract of 3GTS 25.211 that defines the different slot formats for DPCCH/U.

Note: Unfortunately, the slot format to be used is not included in the RRC: RB_SETUP-message in plain text. It needs to be determined by an iterative procedure that is explained underneath. This procedure applies only between RNC and UE, since the RNC *will* convey the slot format to be used through the NBAP-protocol to the NodeB in plain text.

The following numbers relate to the numbers in the text boxes on the previous page.

1. The IE “spreadingFactor” only relates to the minimum spreading factor that the mobile station may use on DPDCH/U. The spreading factor of the DPCCH/U is always $SF = 256$. Consequentially, on DPDCH/U the mobile station may only use slot format 0 ($\Leftrightarrow SF = 256 / 15 \text{ kbit/s}$), slot format 1 ($\Leftrightarrow SF = 128 / 30 \text{ kbit/s}$) and slot format 2 ($\Leftrightarrow SF = 64 / 60 \text{ kbit/s}$).
2. The IE “Number of FBI-bits” is missing. Implicitly, this means that the mobile station shall not include any FBI-bits (Feed Back Information). Consequentially, on DPCCH/U only slot formats without FBI-bits are applicable.
3. The network instructs the mobile station to include a TFCI-field into the DPCCH/U.
4. No compressed mode operation is applicable. Accordingly, the mobile station shall always transmit all 15 slots per radio frame.

Result: The only slot format that fulfills all previous constraints, is slot format #0.

[3GTS 25.211 (table 1, table 2), 3GTS 25.331 (10.3.6.88)]

Configuration of the Size of an RLC-PDU

BITMASK	ID Name	Comment or Value
	RRC_CONN_SETUP	
	1.1.1.1.9 ul-AddReconfTransChInfoList	
	1.1.1.1.9.1 uL-AddReconfTransChInformation	
-----0--	1.1.1.1.9.1.1 ul-TransportChannelType	dch
b5	1.1.1.1.9.1.2 transportChannelIdentity	32
	1.1.1.1.9.1.3 transportFormatSet	
	1.1.1.1.9.1.3.1 dedicatedTransChTFS	
	1.1.1.1.9.1.3.1.1 tti	
	1.1.1.1.9.1.3.1.1.1 tti40	
	1.1.1.1.9.1.3.1.1.1.1 dedicatedDynamicTF-Info	
	1.1.1.1.9.1.3.1.1.1.1.1 rlc-Size	
	1.1.1.1.9.1.3.1.1.1.1.1.1 octetModeType1	
b5	1.1.1.1.9.1.3.1.1.1.1.1.1.1 sizeType1	16

The actual RLC-PDU Size for this DCH/UL is provided in octetmodeType 1:
 $\Rightarrow \text{RLC-PDU-Size} = (8 \times \text{sizeType1}) + 16 \text{ [bit]}$
 $\Rightarrow \text{RLC-PDU-Size} = (8 \times 16) + 16 = 144 \text{ bit}$

Extract of 3GTS 25.331 (ASN.1-Code):

```

OctetModeRLC-SizeInfoType1 ::= CHOICE {
  -- Actual size = (8 * sizeType1) + 16
  sizeType1      INTEGER (0..31),
  sizeType2      SEQUENCE {
    -- Actual size = (32 * part1) + 272 + (part2 * 8)
    part1         INTEGER (0..23),
    part2         INTEGER (1..3)
  },
  sizeType3      SEQUENCE {
    -- Actual size = (64 * part1) + 1040 + (part2 * 8)
    part1         INTEGER (0..61),
    part2         INTEGER (1..7)
  }
}
    
```

Configuration of the Size of an RLC-PDU

The extract illustrates how the UE is informed about the configured TB-size. This happens indirectly through the configuration of the related RLC-PDU-size. The RRC-protocol has different options on how to convey the RLC-PDU-size to its peer in the UE:

- **Octet Mode Type 1, 2 or 3**
The octet mode is applicable, if the TB-sizes shall only vary by at least 8 bit. The different types (\Leftrightarrow sizeType1, 2, 3) allow for the definition of larger or smaller RLC-PDU-sizes by still using the minimum number of bits to identify these sizes. This is achieved through offsets in sizeType2 and sizeType3.
- **Bit Mode Type 1, 2, 3 and 4.**
The bit mode is applicable, if the TB-sizes shall vary in bits.

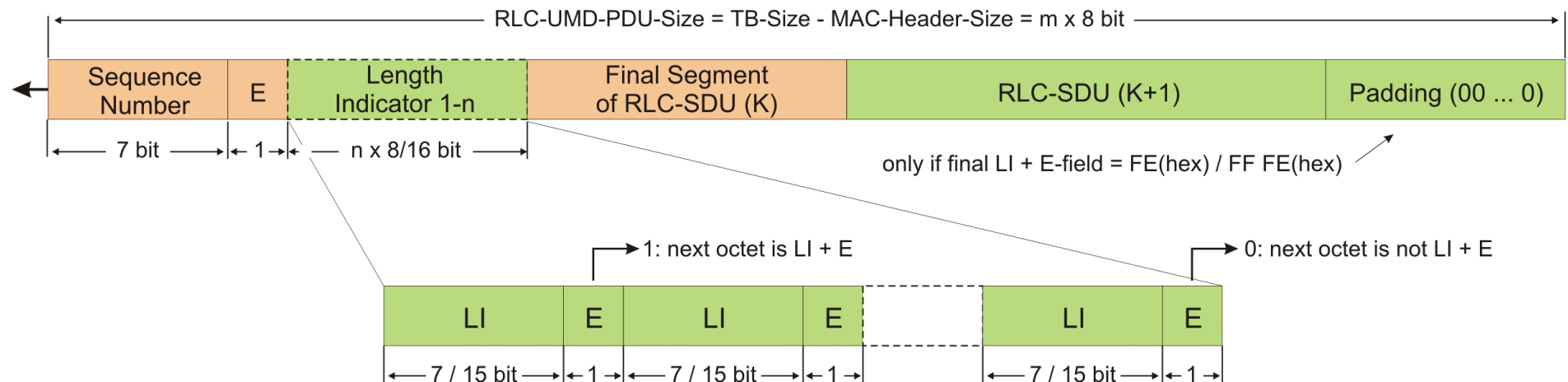
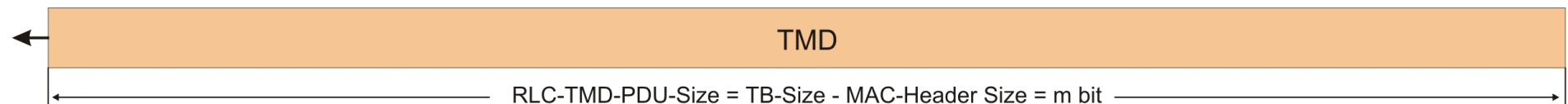
Note the Differences between NBAP (Size Configuration RNC \Leftrightarrow NodeB) and RRC (Size Configuration RNC \Leftrightarrow UE):

- In NBAP, the TB-size is conveyed to the NodeB in plain text (e.g. 360 bit). Considering that $\text{RLC-PDU-size} = \text{TB-Size} - \text{MAC-header size}$, the NodeB needs to know which logical channel \Leftrightarrow transport channel mapping is used (because of the different MAC-header sizes) to determine the RLC-PDU-size.
- The UE needs to approach the problem from the other end. It obtains from the RNC the RLC-PDU-size and the mapping information between logical channels and transport channels. Applying the formula from above, the $\text{TB-size} = \text{RLC-PDU-size} + \text{MAC-header size}$.

[3GTS 25.331]

RLC-PDU-Types

- The TMD-PDU and the UMD-PDU



NOTE: LI = 7 bit \Leftrightarrow UMD-PDU-Size \leq 125 octets
 LI = 15 bit \Leftrightarrow UMD-PDU-Size $>$ 125 octets

RLC-PDU-Types

The TMD-PDU

Most importantly, the TMD-PDU does not include nor require any RLC-header. The TMD-PDU is m bit long whereas m does not need to be a multiple of 8 bit. There are no optional fields in a TMD-PDU.

Note: The size of an RLC-PDU is configured by RRC in e.g. an RRC_CONN_SETUP- or SIB-message.

The UMD-PDU

The UMD-PDU includes a header with a minimum length of 1 octet. Length indicators within an UMD-PDU are only required, if segments from different RLC-SDU's need to be delimited from each other or if padding is used to fill an UMD-PDU to the configured size.

Unlike the TMD-PDU, the length of a UMD-PDU shall be a multiple of 8 bit. In other words, the UMD-PDU will always terminate on an octet boundary.

- **Header Fields**

Sequence Number (7 bit)

The sequence number is modulo 7. It shall be incremented for every new UMD-PDU which is transferred from an UM-sender to an UM-receiver. The initial sequence number for UMD-PDU's from a UE to UTRAN shall be '0'. However, the initial sequence in the direction UTRAN \Rightarrow UE cannot be predicted.

E-Bit

The E-bit or Extension-bit is used to identify whether or not the next octet contains data or a length indicator.

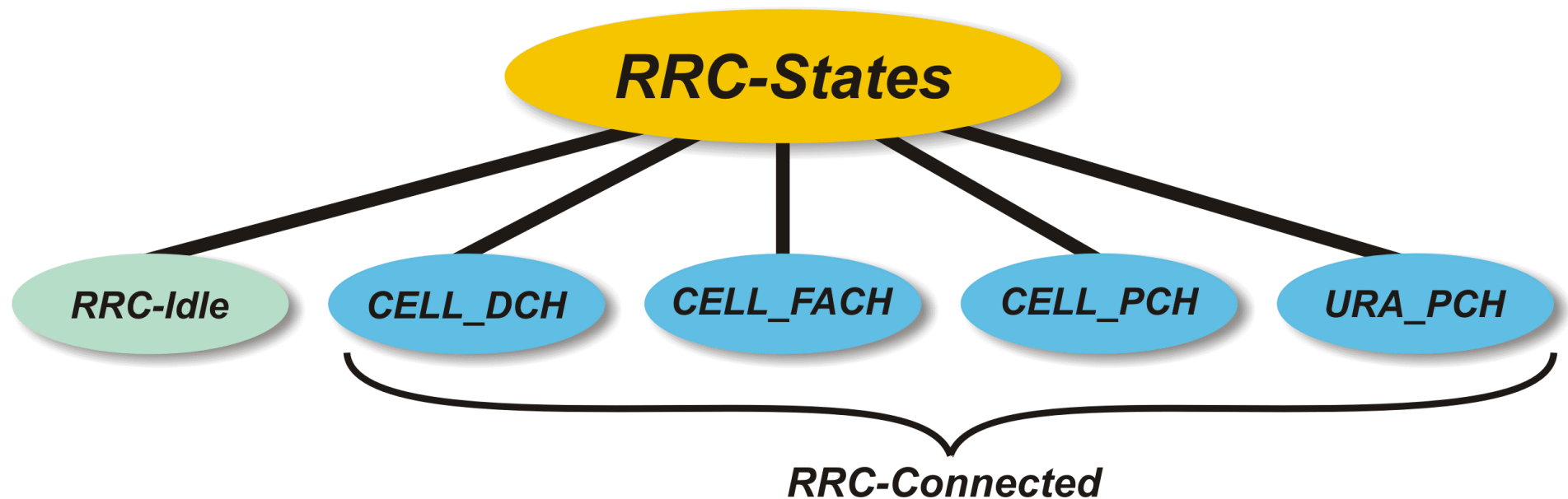
Length Indicator (7 bit / 15 bit) plus E-Bit

Length indicators are used to delimit segments from different RLC-SDU's within a single UMD-PDU from each other. In addition, length indicators are used to identify the start of padding within an UMD-PDU.

Note: 7 bit length indicators are only applicable as long as the configured UMD-PDU-size is ≤ 125 octets. Since 7 bit can represent values up to 127, this requires some explanation: The limitation 125 is due to the fact, that LI-values = 124, 125, 126 and 127 are reserved or are used for special purposes. Considering a minimum UMD-PDU header length of 1 octet plus another octet for the LI + E-octet, this leaves us with a maximum length indication of 123 octets and therefore a maximum UMD-PDU-length of 125 octets, if 7 bit length indicators shall be used.

[3GTS 25.322 (9.2.1.2, 9.2.1.3, 9.2.2, 11.2)]

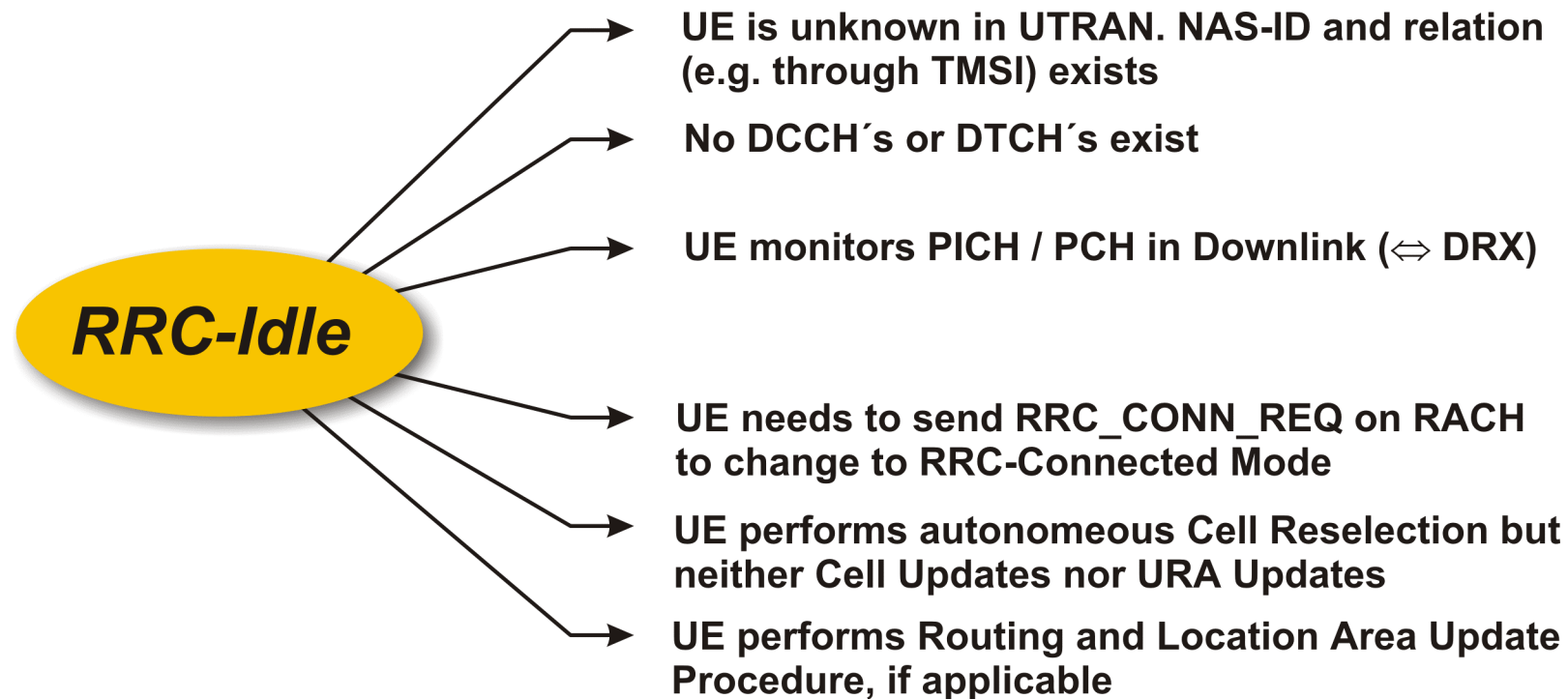
The Different RRC-States



The Different RRC-States

Intentionally left blank

RRC-Idle Mode



RRC-Idle Mode

UE is unknown in UTRAN

This statement relates in particular to the non-existence of RNTI's in the UTRAN for this UE. Still, the UE may be known in the circuit-switched and/or packet-switched core network, if it has previously registered (\Leftrightarrow attachment). In this case, the respective core network entities will also have TMSI and/or P-TMSI allocated to the UE.

No DCCH's or DTCH's exist

Obviously, there can be no dedicated logical channels in RRC-idle mode.

UE monitors PICH / PCH in Downlink (\Leftrightarrow DRX)

Hence, the core network can through UTRAN and the paging procedure request the UE to change to RRC-connected mode.

Change to RRC-Connected Mode requires Transmission of RRC_CONN_REQ

It is only the UE that can decide to trigger the RRC-connection establishment. This happens through the transmission of an RRC_CONN_REQ-message to the RNC. Obviously, the network can request the UE to trigger the RRC-connection establishment by sending a PAG_TYPE1-message on PCCH to the UE.

UE performs Autonomous Cell Reselection but neither Cell Updates nor URA Updates

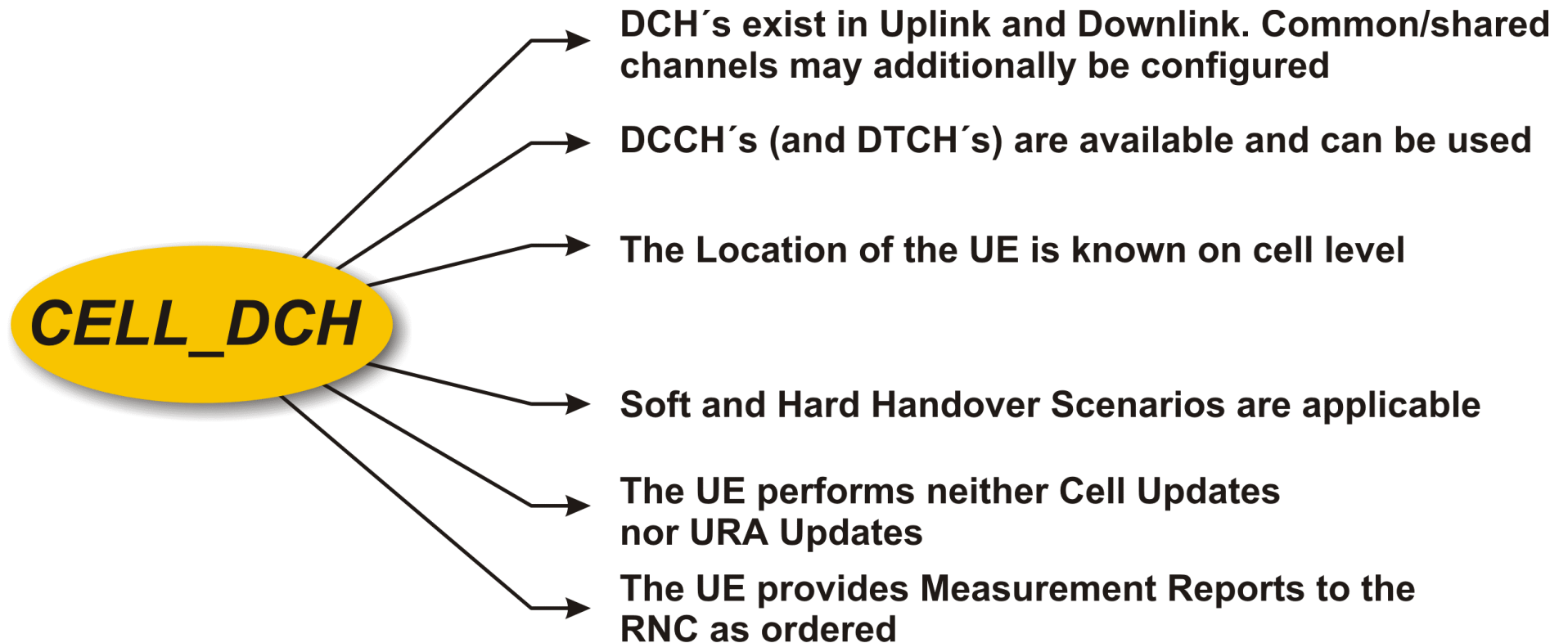
While the UE is in RRC-idle, it will obviously reselect the serving cell based on radio interface criteria (\Leftrightarrow CPICH-measurements) but the UE will not perform cell update or URA-update procedures.

UE Performs Routing and Location Area Update Procedures

If the new serving cell belongs to another routing or location area, the UE shall perform the respective MM-/GMM-procedures, if it is attached to the respective service.

[3GTS 25.304, 3GTS 25.331 (7.2.1)]

CELL_DCH-State



CELL_DCH-State

DCH's exist in Uplink and Downlink Direction

This is the most important characteristics of the CELL_DCH-state. Dedicated TrCH's are available in uplink and downlink direction and can be used for the exchange of DCCH- and, if configured, DTCH-logical channel information. Note that in CELL_DCH-state, common / shared TrCH's may be configured in addition, e.g. for the use by the DTCH's.

DCCH's are available and can be used; DTCH's may be available

Another important characteristics of the CELL_DCH state is that DCCH's are configured. Configuration relates to the mapping between DCCH X to DCH Y. DTCH's may also be configured in addition.

If UTRAN receives a paging message for the UE from the core network, it will use the PAG_TYPE2-message on DCCH (over DCH) to inform the UE. This is possible when the UE has radio access bearers established to one core network domain (e.g. circuit-switched) and UTRAN receives a paging from the other core network domain.

UTRAN knows the Location of the UE on Cell Level

The SRNC has allocated a U-RNTI to the UE and knows the location of the UE on cell level. The allocation of a C-RNTI is not required in CELL_DCH.

Handover Scenarios are Applicable

Only in CELL_DCH-state, soft and hard handover scenarios are applicable. Handover relates to the switching of the dedicated channels to another cell which may be a UTRAN-cell (FDD or TDD) or which may belong to another RAT (e.g. GSM).

UE performs no Cell Updates or URA Updates

In CELL_DCH-state the UE relies on the network to handover the UE to the best possible serving cell. Accordingly, neither cell updates nor URA-updates are applicable.

Exceptions:

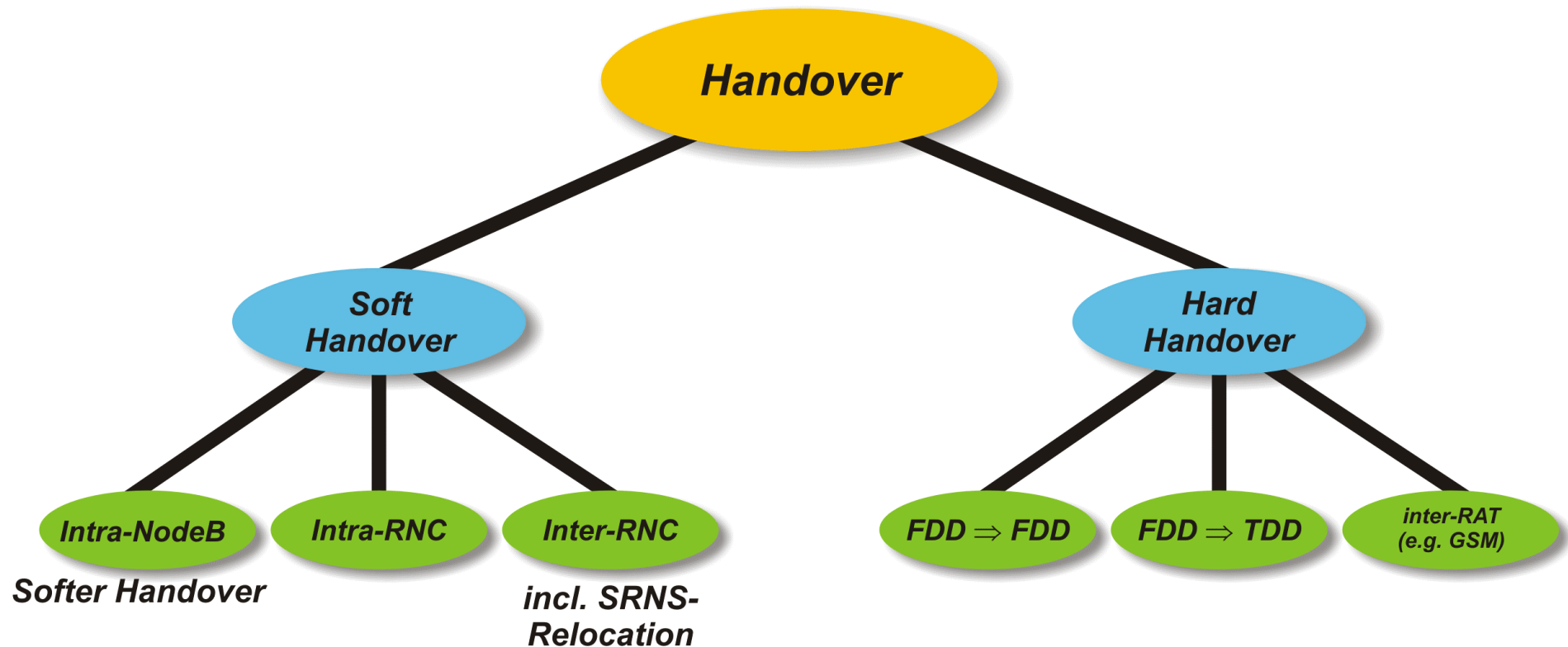
1. In case of a radio link failure or RLC-AM unrecoverable error in CELL_DCH-state, the UE shall initiate a cell update scenario with cause "radio link failure" and the network shall consecutively initiate the release of the RRC-connection by sending RRC_CONN_REL to the UE [3GTS 25.331 (8.3.1.2)].
2. In CELL_DCH-state, UTRAN may also initiate a cell change to a GERAN-cell by sending a CELL_CHAN_UTRAN-message to the UE, if the UE has only radio bearers established towards the packet-switched domain.

UE provides Measurement Reports to the RNC

Which measurements the UE performs depends on the setup information received from the RNC (⇔ SIB 11 and 12 / MEAS_CTRL-message).

[3GTS 25.331 (7.2.2.3, Annex B.3.1)]

Handover Scenarios



Handover Scenarios

- **Soft Handover Scenarios**

In a soft handover scenario the UE is not interrupting the link to its serving cell while another radio link is added from a different cell. Soft handover is also applicable when an active radio link is deleted between the UE and one of the serving cells.

Note: All soft handover scenarios are intra-frequency handover scenarios.

The following soft handover scenarios have to be distinguished:

- ⇒ Softer Handover / Intra NodeB
- ⇒ Soft Handover / Intra-RNC and Inter-NodeB
- ⇒ Soft Handover / Inter RNC (⇔ incl. SRNS-Relocation)

- **Hard Handover Scenarios**

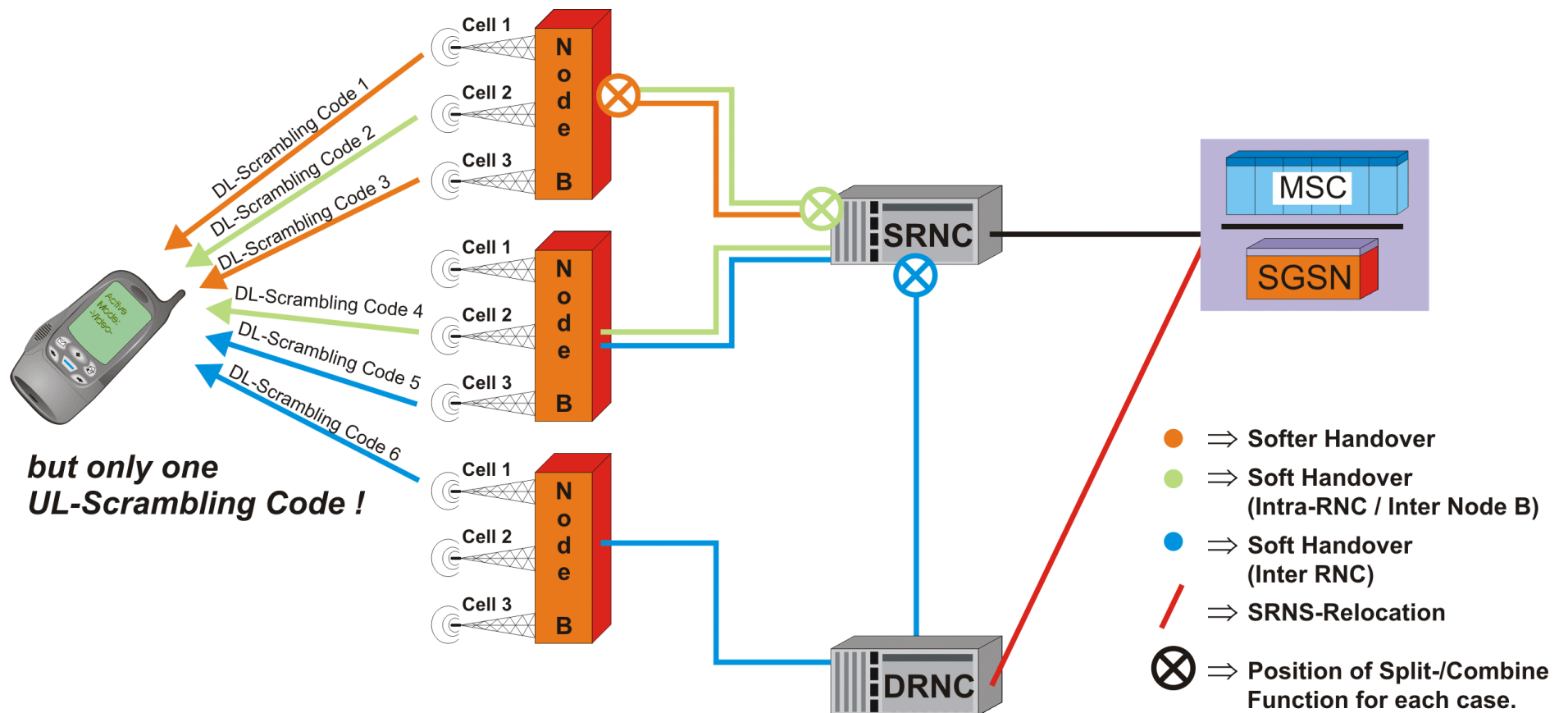
Hard handover scenarios are all handover scenarios in which the active radio link is replaced by another radio link, most likely in a different cell and possibly in a different RAT (radio access technology). The following hard handover scenarios have to be distinguished:

- ⇒ Handover from FDD-Frequency 1 to FDD Frequency 2
- ⇒ Handover from FDD to TDD
- ⇒ Handover from UTRAN to another RAT (e.g. GSM)

Note:

- All soft and hard handover scenarios are only applicable in CELL_DCH-state and are always controlled by the SRNC.
- In CELL_DCH-state, the SRNC may also order a cell update procedure to GSM/GPRS by sending an RRC: CELL_CHAN_UTRAN-message to the UE, if there are no DCH's configured towards the circuit-switched core network domain.
- In CELL_FACH-state, both the SRNC and the UE may decide for a cell update procedure. In this case, UTRAN would send an RRC: CELL_CHAN_UTRAN-message to the UE or, if the UE decides autonomously, the UE will just perform a cell reselection to the respective GSM-cell and perform a GPRS-cell update procedure or a routing area update procedure, if the GSM-cell belongs to a different routing area.

Variations of Soft Handover



Variations of Soft Handover

For soft handover, different variations exist. Depending on the variation, the split/combine function in uplink direction (network side) will be located either in the NodeB or in the SRNC.

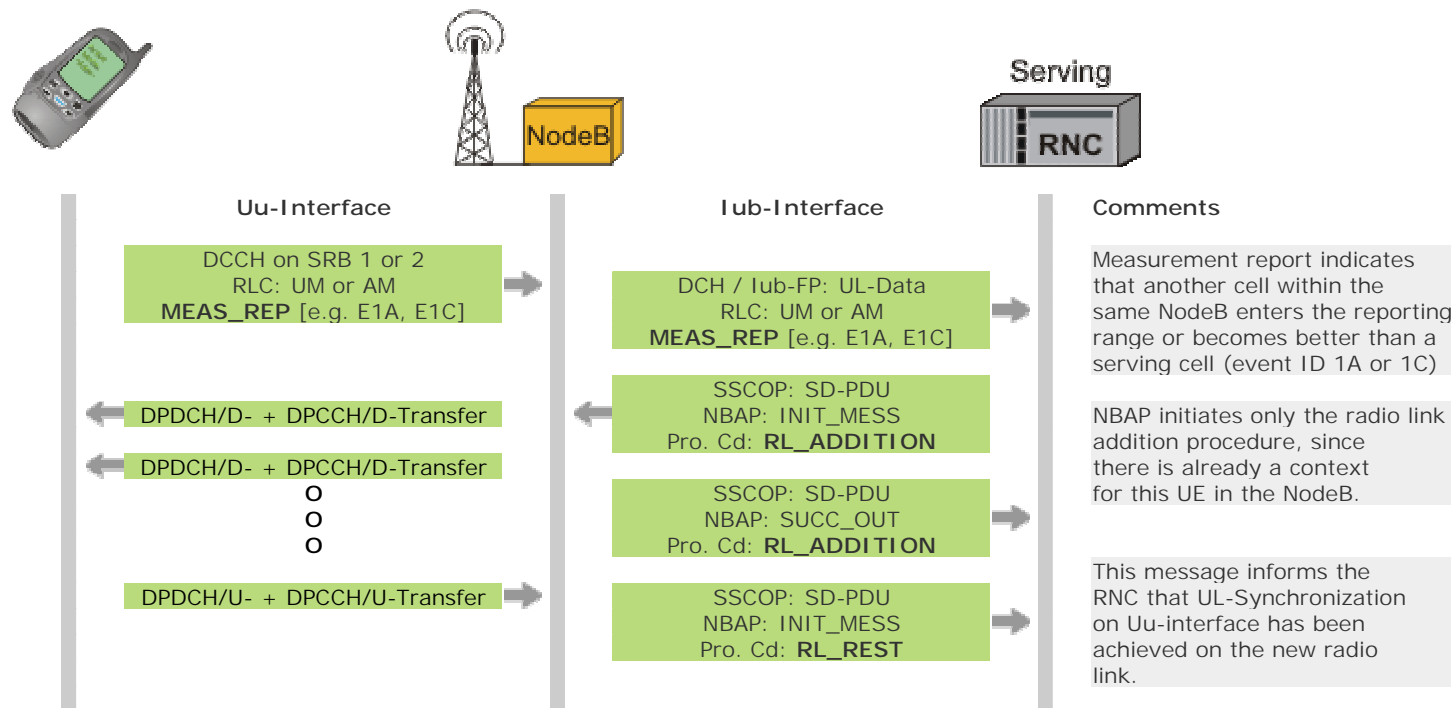
Note:

- In a soft handover situation, the UE shall be able to support a minimum of 6 active radio links to 6 different cells simultaneously [3GTS 25.133 (5.1.2.1)].
- Each cell will use another scrambling code in downlink direction while the UE will use only one uplink scrambling code.
- At least in theory, each of these cells may be connected to another RNC.
- With SSDT (Site Selective Diversity Transmission) there can be maximum 8 simultaneously received cells [3GTS 25.214 (5.2.1.4)].

SRNS-relocation is only indirectly related to soft handover: An SRNS-relocation will be initiated by the SRNC when a (hard or soft) handover procedure results in the radio link removal of the last cell which is controlled by the SRNC.

Note: A DRNC may be connected to a separate MSC/VLR than the SRNC.

(1) Softer Handover (Radio Link Addition)



(1) Softer Handover (Radio Link Addition)

Initial Conditions

The UE is in CELL_DCH-state and is connected to one or more NodeB's. The SRNC has previously configured intra-frequency measurements for the UE. Measurement reports shall be sent event triggered. Intra-frequency measurements indicate that another cell enters the reporting range (\Leftrightarrow Event 1A) or that another non-active cell becomes better than an active cell (\Leftrightarrow Event 1C). This triggers the transmission of a MEAS_REP-message.

Applicability of this Procedure

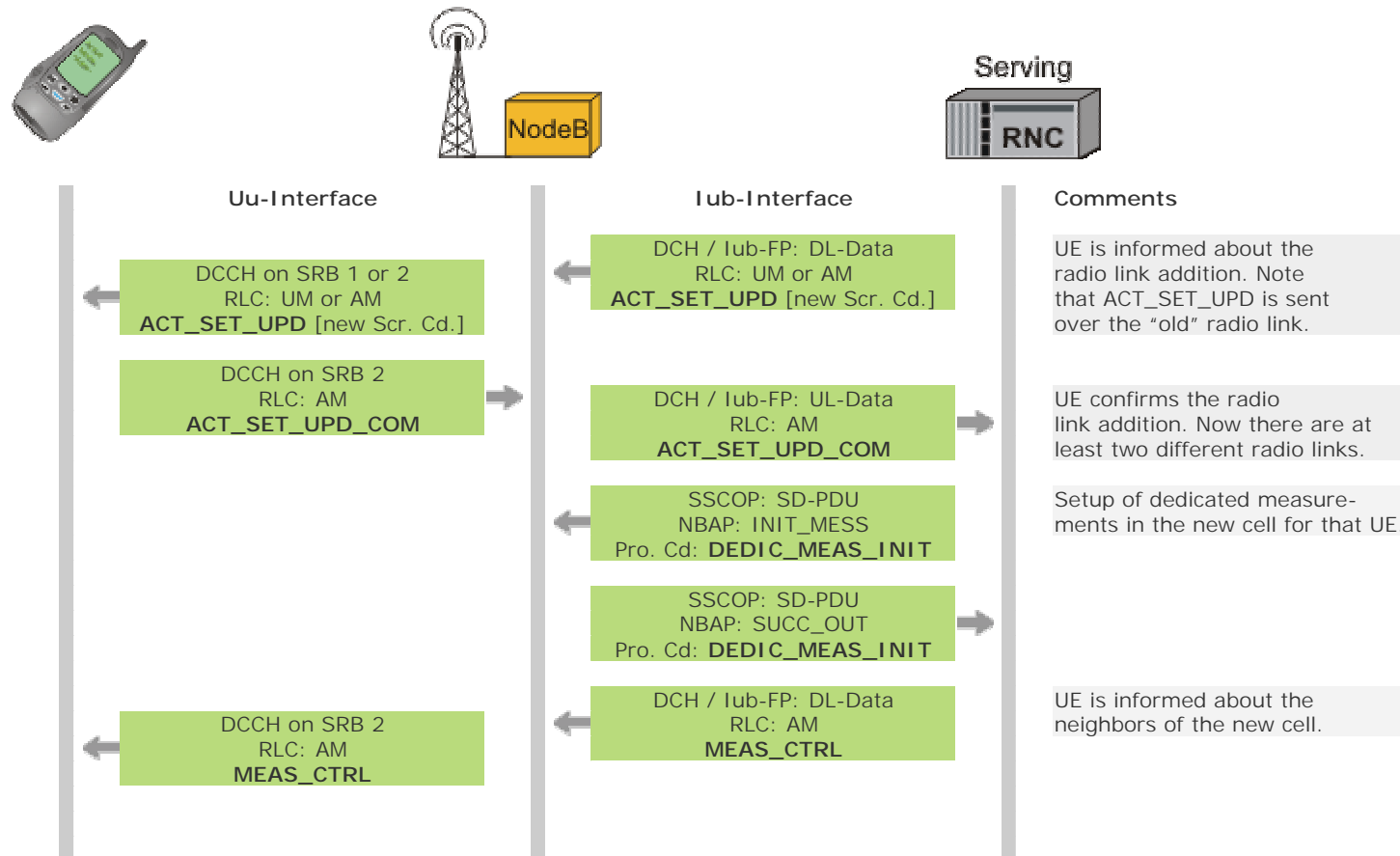
The presented procedure is only applicable if the new radio link is established within a NodeB where the UE already has setup one or more active links to cells of this NodeB. Obviously, this remains transparent to the UE.

Description

- \Rightarrow The UE will initiate the procedure by sending a MEAS_REP-message to the SRNC. The MEAS_REP-message is sent because another non-active cell enters the reporting range (\Leftrightarrow Event 1A) or another non-active cell becomes better than an active cell (\Leftrightarrow Event 1C). The measurements are based on the CPICH RSCP or the CPICH Ec/No of the different cells.
- \Rightarrow The SRNC will send an NBAB: RL_ADDITION-message (initiating message) to the NodeB that controls the cell to be added to the active link set. The NBAP: Radio Link Addition procedure is used because there is already a communication context existing between the SRNC and the NodeB for this UE (\Leftrightarrow softer handover). Accordingly, the NBAP: RL_ADDITION-message will include the same CRNC-Communication Context ID that the previous NBAP-messages from the SRNC to the NodeB for this UE related to.
- \Rightarrow Among other things, the RL_ADDITION-message identifies the UE (and its scrambling and channelization code) within the NodeB and it tells the NodeB which scrambling code to use in the target cell in downlink direction (most likely DL-Scrambling Code = 0 which relates to the primary scrambling code of the cell).
- \Rightarrow In the case of softer handover, there is no new AAL-2 link nor DCH established between the NodeB and the SRNC because the split/combine-function will reside in the NodeB rather than in the SRNC.
- \Rightarrow After the reception of the NBAB: RL_ADDITION-message (initiating message) the NodeB will start to transmit data on DPDCH/D and DPCCH/D to the UE. Note that this data cannot yet be received by the UE, since it is still unaware of the new radio link. The NodeB will also confirm the radio link addition procedure by sending an NBAB: RL_ADDITION-message (successful outcome) to the SRNC.
- \Rightarrow When the NodeB has successfully achieved uplink radio link synchronization on the Uu-interface it will send an NBAP: RL_REST-message (initiating message) to the SRNC. Note that in this case synchronization procedure B is used, because there have already been one or more active links prior to the synchronization of this active link.

Note: At this time, radio link synchronization has only been achieved in uplink direction but not in downlink direction.

(2) Softer Handover (Radio Link Addition)



(2) Softer Handover (Radio Link Addition)

Description

- ⇒ The SRNC will initiate dedicated uplink measurements for that UE in the new cell by sending one or more NBAP: DEDIC_MEAS_INIT-messages (initiating message) to the NodeB which controls the new cell.
- ⇒ The NodeB will confirm measurement setup by sending NBAP: DEDIC_MEAS_INIT-messages (successful outcome) back to the SRNC.
- ⇒ Consequently, the SRNC will build an RRC: ACT_SET_UPD-message and send it to the UE using the already established (old) downlink DCH to the UE. Most importantly, this message identifies the scrambling code of the cell which has been added to the active link set.
- ⇒ The UE will immediately perform physical layer synchronization procedure B to synchronize to the new radio link.
- ⇒ Without waiting for a successful downlink radio link synchronization of the new radio link the UE shall send an RRC: ACT_SET_UPD_COM-message to the RNC.
- ⇒ Finally, the SRNC will update the measurement configuration of the UE with respect to the new active cell (new neighbor cells) by sending a MEAS_CTRL-message to the UE.

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