APPENDIX 1
Basic UMTS Procedures

Procedures

1. UMTS PROCEDURES – GENERAL

1.1 UMTS Defined Procedures

The procedures described in the first phase of UMTS specifications concentrate predominantly on the air interface and UTRAN.

The Core Network is considered as an evolved GSM network, hence the procedures are those specified for the GSM Core Network, including GPRS. As network operators move to an All-IP network, the procedures in the core network will reflect this and will be based more on the IETF (Internet Engineering Task Force) specifications.

As the core network is not the subject for UMTS standardisation, it follows that the way it interacts with UE will remain essentially that specified for GSM. Hence, when considering UMTS procedures, we can initially concentrate on the Air Interface and UTRAN.

It is still useful to examine the Non-Access stratum and Core Network procedures in order to show the overall system operation, and how UTRAN and Air Interface procedures fit into the bigger picture.

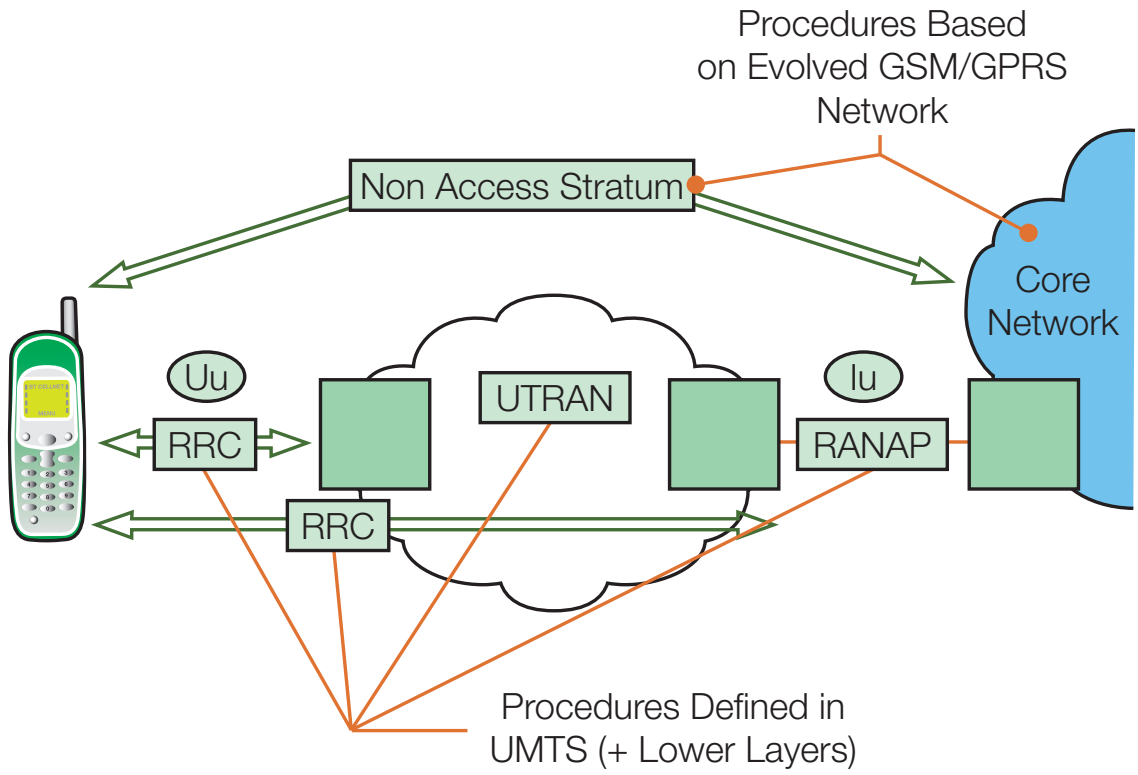


Fig. 1 – UMTS Procedures - General

1.2 UE Identifiers (Held by the User Equipment and Core Network)

The identifiers held by the User Equipment and Core Network are shown opposite:

The IMSI (International Mobile Subscriber Identity) is used in the network to identify the Subscriber Identity Module (SIM), or UMTS SIM (USIM) within the mobile. It is held within the location registers in the network against information, including the services supported, current location (down to Location Area - LA or Routing Area – RA only), and status for that mobile. It is unique to the mobile in question as it reflects the Mobile Country Code, Mobile Network Code, and Subscriber Identity within that network.

The TMSI (Temporary Mobile Subscriber Identity) is used as a code word for the IMSI over the radio interface. It is shorter than the IMSI and unique only within the Visitor location Register (VLR) / Mobile Switching Centre (MSC) area. It is changed at regular intervals by the VLR in order to maintain security.

The P-TMSI (Packet TMSI) is essentially similar to the TMSI, but is used in the Serving GPRS Support Node (SGSN) rather than in the VLR. Again, it is used as a code word and changed at regular intervals.

The IMEI (International Mobile Equipment Identity) is used to identify the mobile equipment itself, rather than the subscriber (via the Subscriber Identity Module). Through its numbering structure it gives details of the manufacturer, model, type approval code, and importantly in terms of procedures, its capabilities can therefore be assessed.

The TLLI (Temporary Logical Link Identity) is used between the SGSN and User Equipment to identify the established logical link for packet services. It is unique within the Routing Area.

- IMSI
- TMSI
- P - TMSI
- IMEI
- TLLI

Fig. 2 – (Core Network) UE Identities

1.3 UTRAN Identifiers

The procedures defined within the UTRAN are extensive. Since mobility is an essential requirement of any mobile network, it is important to be able to identify the elements and areas concerned. The figure shown opposite illustrates how the different elements within the UTRAN are identified.

It shows how the network elements are identified, together with the cell areas and the Public Land Mobile Network itself.

The UE may have Radio Network Temporary Identifiers (RNTI) assigned by the Serving, Drift and Controlling RNC. It allows a level of identification separate to that used by the Core Network (IMSI / TMSI), which allows some mobility procedures to be handled entirely within the UTRAN. The RNTIs are applicable to the Serving, Drift, or Controlling RNC. These are otherwise known as the Cell RNTI.

The U-RNTI is also used for certain procedures, which is a “long” UTRAN UE identity used to ensure routing of uplink messages to the UE’s Serving RNC, irrespective of the receiving RNC.

The cell is identified (UTRAN Cell Id) using a hierarchical scheme which takes its controlling RNC Identity and adds a cell identity to it. Because the Global RNC Identity includes the Public Land Mobile Network Identifier (PLMN Id), it is a unique identifier, and so therefore is the UTRAN Cell Id. The PLMN Id is made up of a Mobile Country Code and Mobile Network Code.

From the UTRAN, the core network domains use identifiers which include the PLMN Id and either the Location Area Code (LAC) for the Circuit Switched Domain, or the LAC and Routing Area Code (RAC) for the Packet Switched Domain.

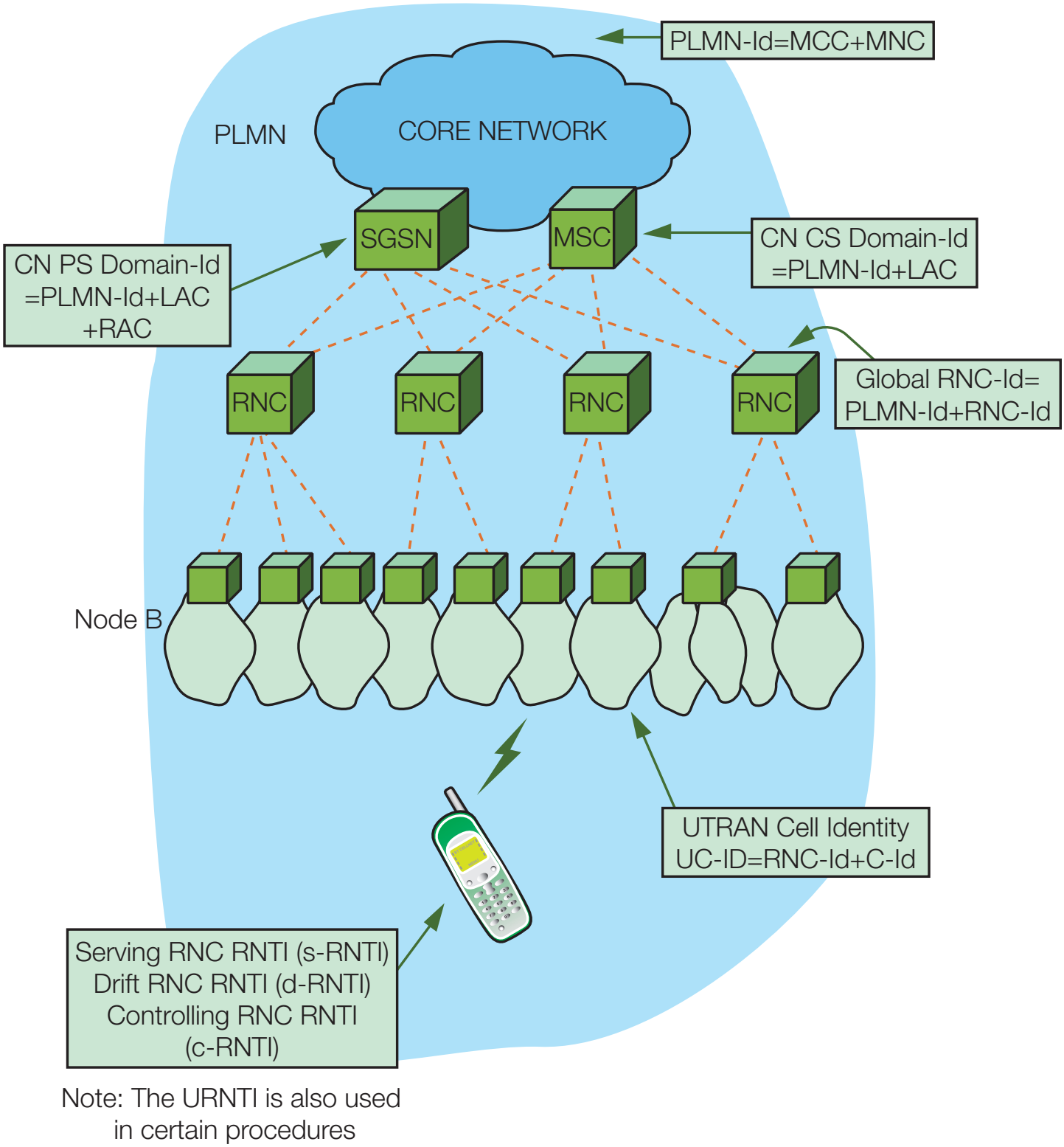


Fig. 3 – UTRAN Identifiers

1.4 UMTS Areas

The cells in UMTS are organised into a series of areas for mobility purposes.

The basic area is that of the cell itself.

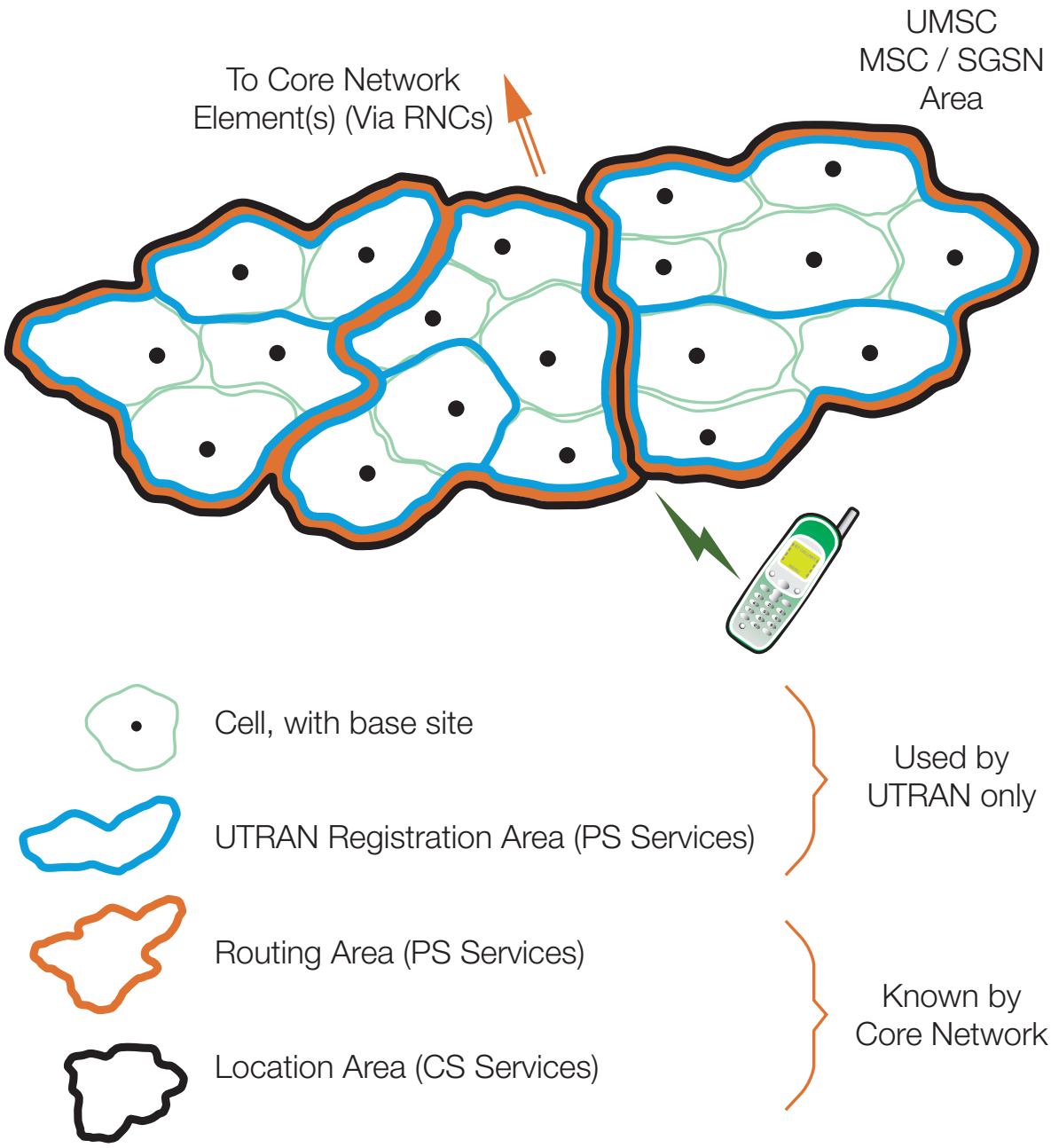
A number of cells (varying from a single cell to all the cells in the area served by a Core Network Node, i.e. MSC / VLR area), are grouped into location areas. A mobile is tracked on a location area (LA) basis by the Visitor Location register (VLR). Any incoming calls result in the mobile being paged over all the cells in the Location Area. This negates the need for the mobile to update its position constantly as it moves from cell to cell when it would otherwise be in idle mode (saving power and reducing interference and load on the radio network). Of course, a bigger LA requires more cells to carry the paging message.

The Routing Area (RA) is a subset of the LA (with cells numbering between one and all the cells in the LA). The boundary of the RA must be coincident with, or confined within the LA boundary. The RA is used in the Packet Switched Core Network in a similar way that the LA is used in the Circuit Switched, but it gives a greater degree of accuracy and flexibility.

In addition, the UTRAN Registration Area (URA) is specified for use within the UTRAN (the Core Network is not aware of this area). Once in the connected mode, the mobile is allowed to fall back into a less active state if using shared channels (only applicable for packet services). In this case, the UTRAN can track the mobile on a cell-by-cell or URA-by-URA basis. The mobile will signal the UTRAN if it changes cell or URA area respectively. So far as the Core Network is concerned, the mobile is still in connected mode. This means data is forwarded through to the UTRAN as if the mobile were connected, without any paging being initiated. The UTRAN would then initiate the paging to bring back the mobile into a more active connected mode.

A cell can belong to several URAs at once. Only if the mobile detects that its current URA is not on the list within its current cell would a URA update procedure be executed. This reduces the signalling required to inform the Serving RNC of the mobile's current location.

Other areas used in relevant procedures include RNC, MSC, VLR and SGSN.



- In addition, RNC, MSC, VLR and SGSN areas are all identifiable.

Fig. 4 – UMTS Areas

2. EXAMPLE RRC PROCEDURES

2.1 RRC Idle Mode

The tasks of the mobile in idle mode are shown opposite:

The mobile continuously monitors the System Information Broadcasts on the Broadcast Channel, interpreting the information appropriately. This information contains parameters such as the serving cell id, UTRAN registration area identities and information on how to access the network (random access information – codes and slots).

The mobile selects the Public Land Mobile Network, and the required cell, based on measurements taken on the radio interface, and the cell selection / reselection algorithms.

Once the cell is selected, the mobile leaves the idle state to register its location with the network. In the absence of any other activity, it then falls back to the idle mode, to monitor the paging channel (within its assigned paging block), updating its location as required (periodically, or as Location Area or Routing Area boundaries are transited).

IDLE MODE:

- Monitor System Information Broadcast (Contains MM Information).
- PLMN Selection and Reselection
- Cell Selection
- Cell Reselection
- Location Registration and Updating
- Monitor Paging Channel/Block

Fig. 5 – RRC Idle Mode

2.2 RRC Connection Establishment

This is instigated from Idle mode. The RRC Connection Request is sent from the mobile to the controlling RNC (which becomes the Serving RNC as the connection is established) on a Common Control Channel, CCCH (which is a bi-directional logical channel used to transfer control information between the network and UEs). The CCCH is always mapped in the uplink to the Random Access Channel (a transport channel), which itself allows mobiles to access the network randomly as a requirement arises. This may be to make a call, transfer data, or update a Location or Routing Area.

The Serving RNC now sets up the Radio Link over the Iub interface, including the data bearer setup within the ATM (Asynchronous Transfer Mode) transport network. Once achieved, the RRC Connection setup indication is sent to the UE over the CCCH (now using the Forward Access Channel, FACH (a transport channel) in the downlink.

The mobile now moves into the connected state, sending a RRC Connection Setup Complete indication to the Serving RNC on the designated dedicated channel.

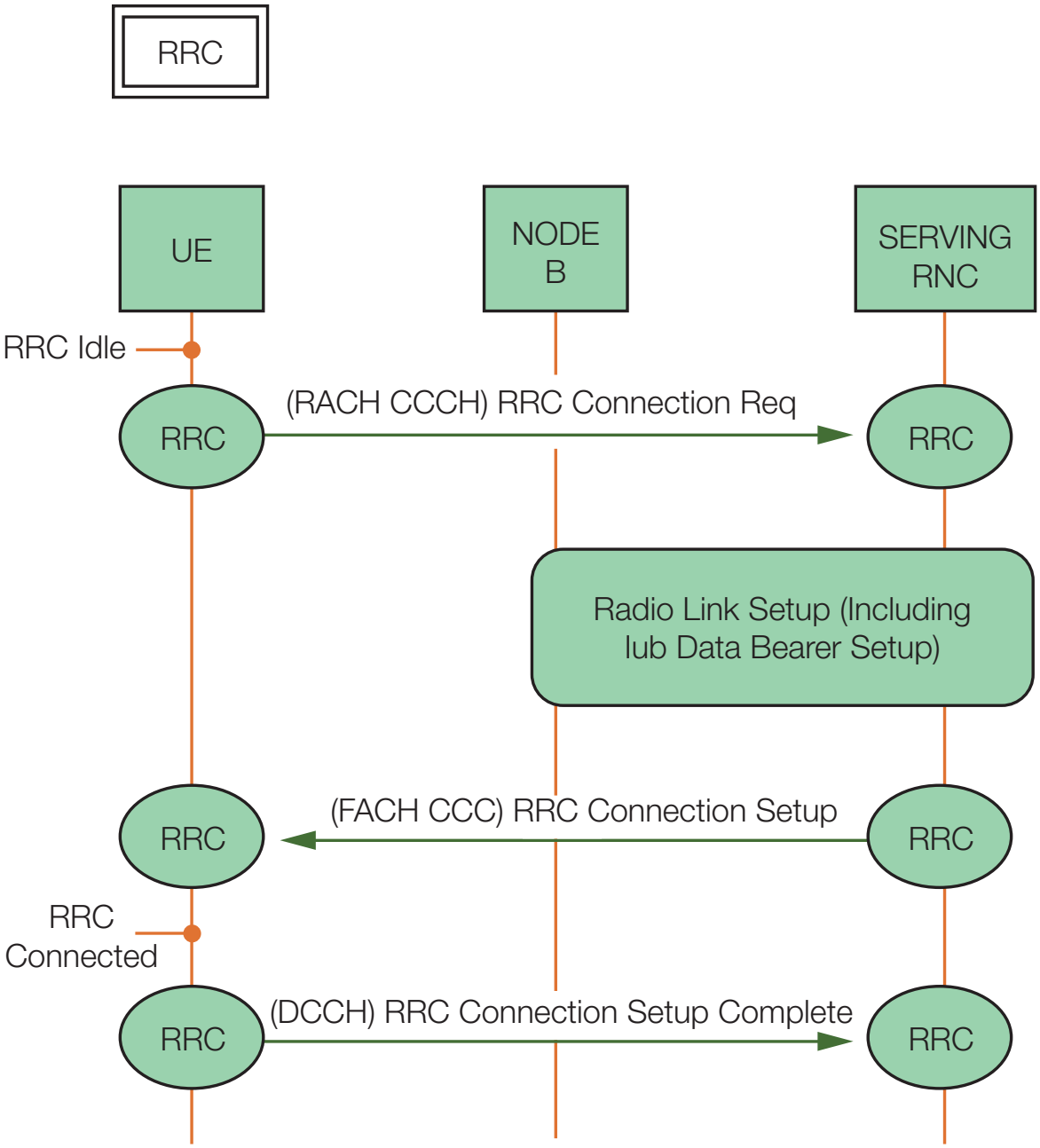


Fig. 6 – RRC Connection Establishment (DCH)

2.3 Paging

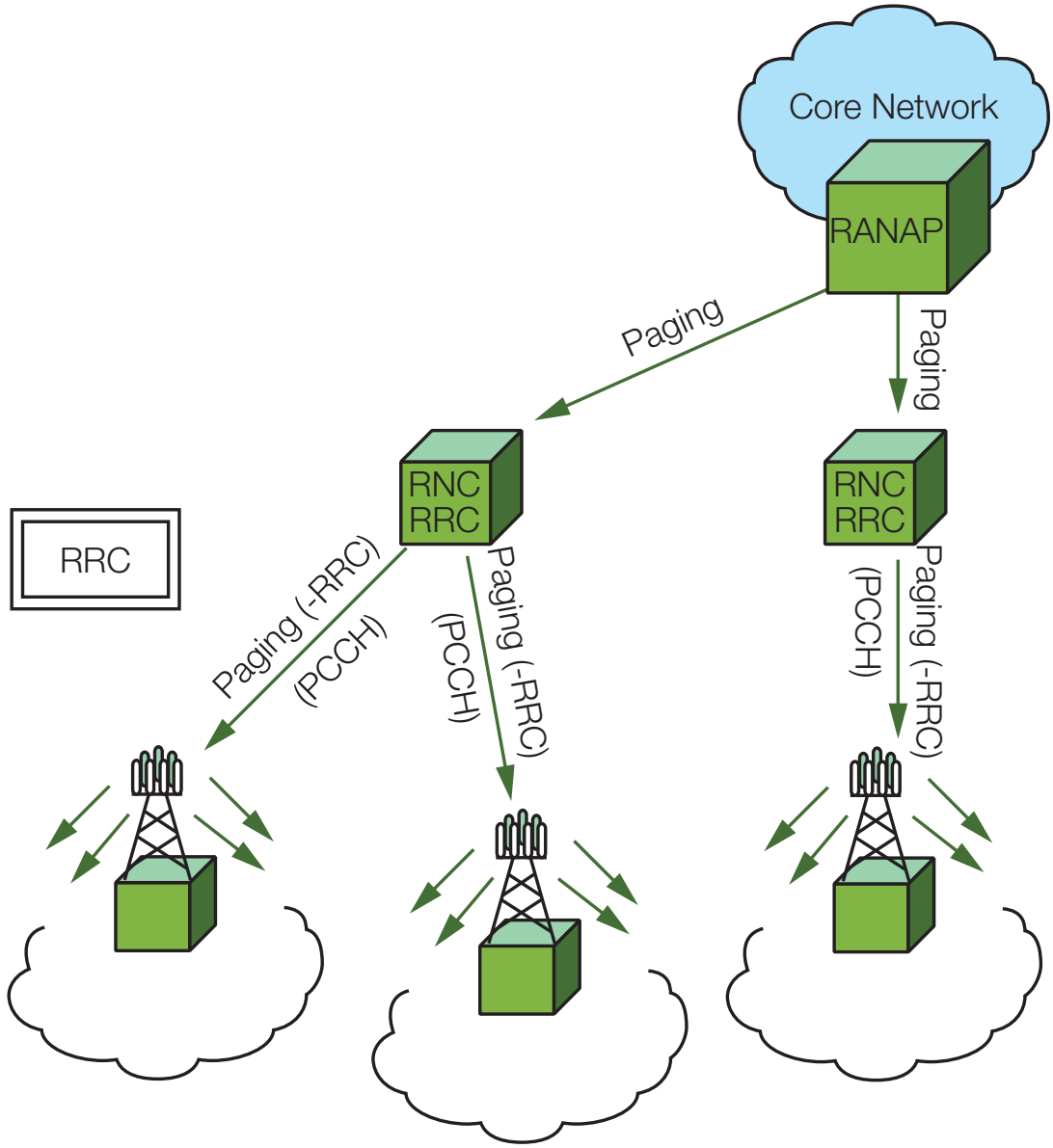
Paging can be initiated either by the Core Network, for mobiles in Idle Mode, or by the Serving RNC for mobiles in the URA_PCH or Cell_PCH mode.

For Idle mobiles, the paging is initiated over the required Location Area, or Routing Area for incoming calls, or for session setup in the case of packet services. The core network node (MSC / VLR or SGSN) initiates the procedure over the Iu interface using RANAP (Radio Access Network Application Part) signalling in this case.

If the mobile is in the URA_PCH or Cell_PCH state, the Serving RNC responds to incoming (downlink) packet data activity by paging the mobile over the appropriate URA or Cell respectively. This is done to bring the mobile into the Cell_FACH state ready for data transfer.

In core network initiated, or RNC initiated cases, the Paging message is broadcast by RRC on the PCCH (Paging Control Channel).

In addition, the RNC can indicate a change of system information by using a paging message with no paging record, but with the new information carried within it. These messages would be aimed at all UEs in a cell.



- Core Network knows LA or RA of UE
- Applicable to RRC Idle Mode (No RRC Connection), or RRC Connected Mode Cell_PCH and URA_PCH states
- For RRC Connected Mode (Cell_DCH and Cell_FACH), DCCH would be used with existing RRC connection – no paging required

Fig. 7 – Paging (Eg RRC Idle Mode)

2.4 Handover Types

There are three different handover types in UMTS:

The **Softer** handover is where the mobile receives the signal via two radio interfaces at the same time, both interfaces being provided by the same Node B. The information from the different sectors, or cells, is handled by the same Node B, hence combining is done within the Rake receiver.

The **Soft** handover is where the mobile receives the signal via two radio interfaces at the same time, but the interfaces are provided by different Node Bs. The information from the different cells is channelled from both Node Bs to the serving RNC (possibly via a Drift RNC) handled by different Node Bs, hence combining is done now in the RNC.

Hard handover is the same sort of handover found in GSM, where the new radio resources are established, and the mobile makes contact via the new resources before the old resources are released. Communication only ever occurs via a single interface. This can be used for handover between WCDMA frequencies, or between different systems.

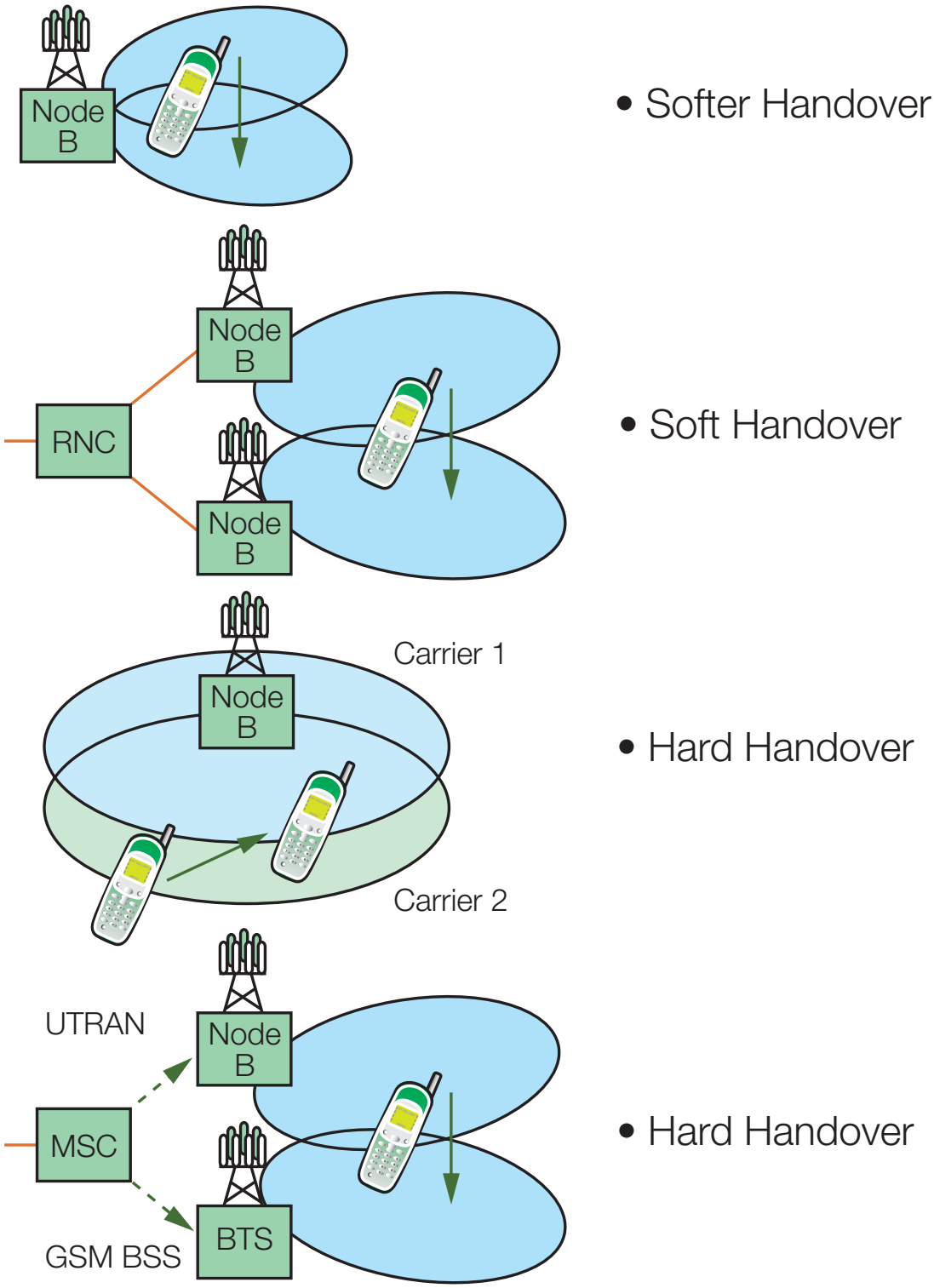


Fig. 8 – Handover Types

2.5 Compressed Mode

For a mobile to monitor resources, on anything other than the WCDMA frequency it is currently using requires a break in reception. This is required because the mobile cannot operate on two frequencies, or therefore on two systems, at once, and WCDMA operation is continuous (unlike Time Division Multiple Access (TDMA) systems, such as GSM, which effectively have gaps between time slots which are used to monitor other cell transmissions).

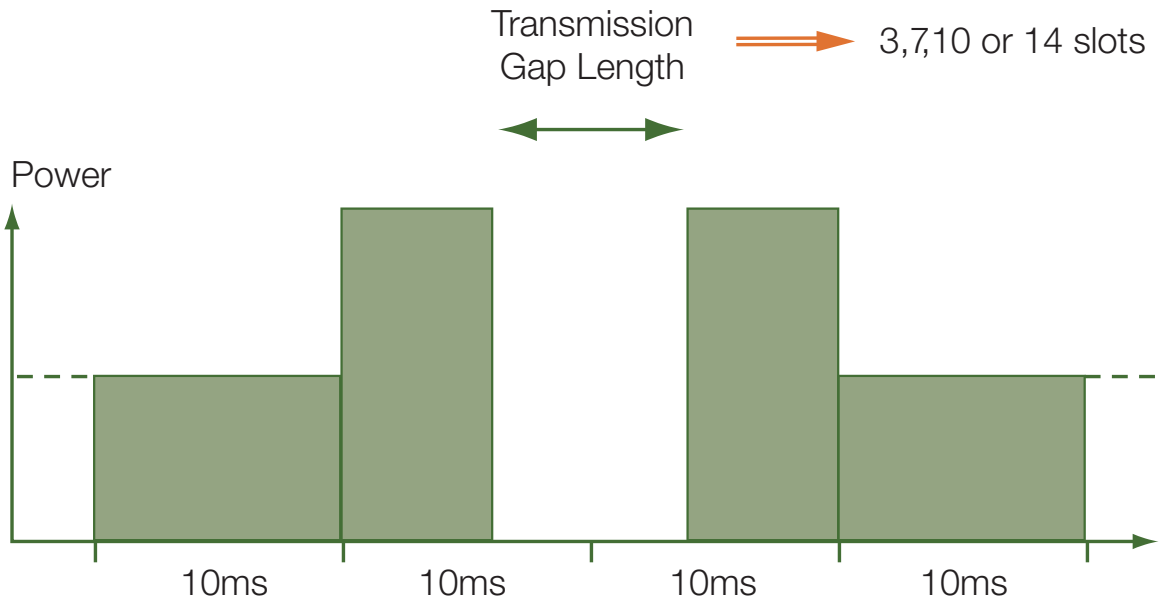
Compressed mode is used in WCDMA to give the break required. It is a technique used to compress (rather than lose) data in order to provide a sufficient gap.

In normal operation, each frame is 10ms long, the time taken to transmit the data can be compressed by:

- Reducing the data rate from the upper layers (although in this case, less data is actually transmitted)
- Lowering the spreading factor so that fewer chips are used to represent the same amount of data (same amount of data transmitted, but with potentially poorer quality)
- Reducing the symbol rate by “puncturing at the physical layer” (taking out unnecessary data, and relying more on forward error correction to maintain quality)

Each frame is made up of a possible 15 slots, and two adjacent frames would therefore have 30 slots available. Out of the 30 slots, 3, 7, 10, 14 slot gaps can be configured.

Compressed Mode - Allows time for other UMTS frequencies to be measured.



Achieved by:

1. Lower data rates from upper layers.
2. Increasing data rate by changing spreading factor.
3. Reducing symbol rate by “puncturing” at physical layer.

Fig. 9 – Compressed Mode (Slotted Mode)

3. NON-ACCESS STRATUM PROCEDURES

3.1 The Mobility Management Concept

The mobility management concept is illustrated opposite. The system needs to know where the mobile is in all states other than detached.

For idle mode, the core network tracks the mobile, whilst in dedicated mode, the UTRAN tracks the mobile. Essentially two levels of mobility management exist.

In idle mode, the mobile monitors the selected and adjacent cells, reselecting where necessary and listening to the system information in each cell.

The network does not need to know precisely where the mobile is, but for the circuit switched domain, needs to know the Location Area (LA) in order that it can page the mobile for incoming calls. For the packet switched domain, the network tracks down the mobile to Routing Area (RA), which may be coincident with the LA, or a subset of it. The mobile will leave the idle mode and enter the connected mode in order to perform the LA or RA updates.

In connected mode, the handover is used with dedicated channels for both circuit switched and packet switched connections. This is sufficient for the UTRAN to track the mobile.

In cases where shared channels are being used (Cell_FACH, Cell_PCH or URA_PCH), the mobile keeps the UTRAN informed of any changes to its cell or UTRAN Registration Area (URA) respectively. No information is exchanged with the core network.

A cell can belong to several URAs in order to stop the ping-pong effect of mobiles near to URA boundaries. Only if the new cell does not belong to the existing URA will an update be made.

Serving Radio Network Sub-system (SRNS) relocation decisions are made in cases of URA or cell updates into new RNC areas. The existing SRNC makes the relocation decision, and not the target RNC. In this case, the core network would be involved in relocating the Iu interface.

Although closely related to inter RNC updates, and occurring at the time of the update, this is considered a separate procedure. The SRNS Relocation procedure is applicable only to the connected mode.

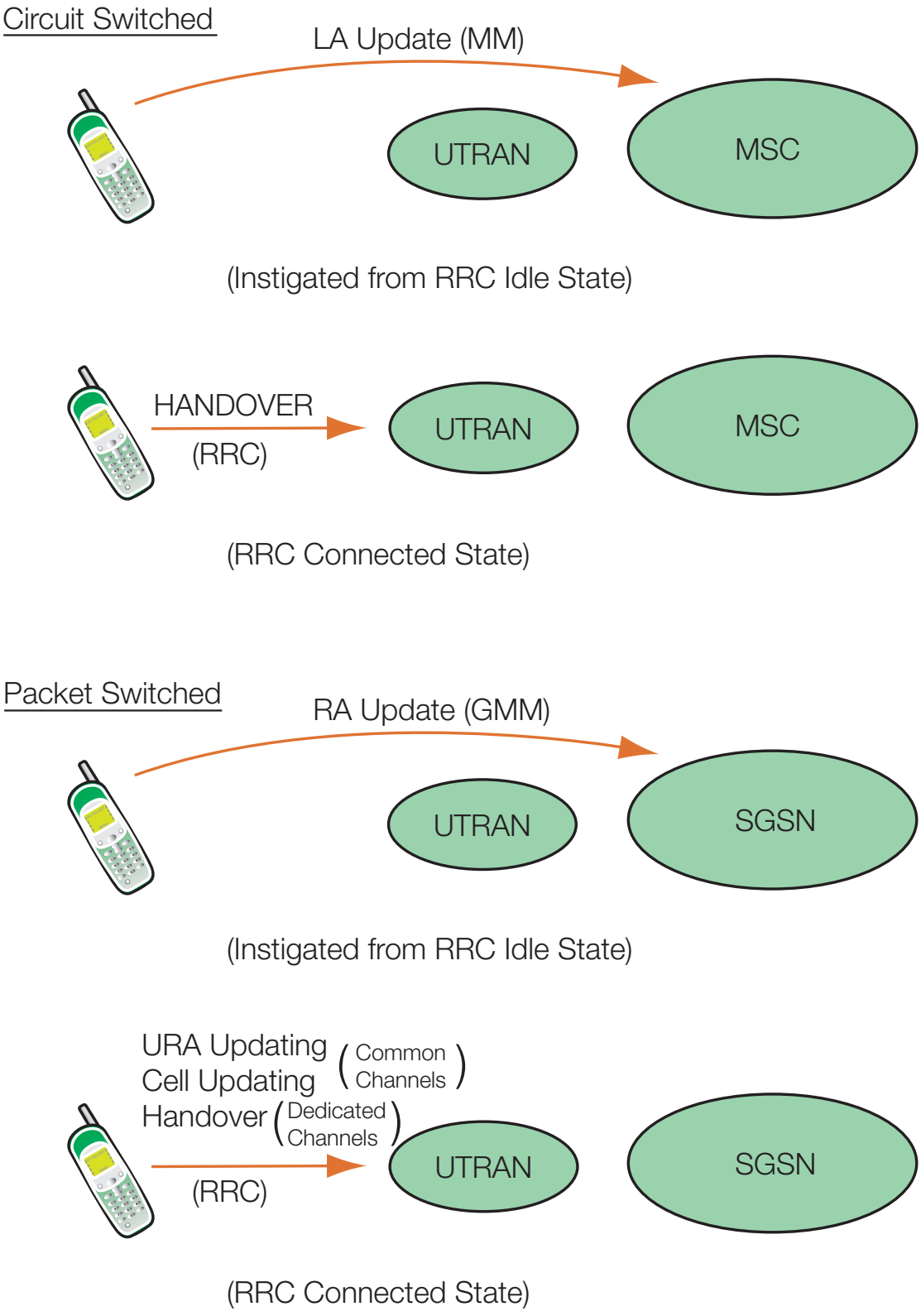


Fig. 10 – The Mobility Management (MM) Concept

3.2 NAS Procedures Example – Service Registration and Updates

Registration is essentially a location update which occurs when a mobile is initially switched on. The other two scenarios when a location update is performed are on a periodic basis (the period to be used is broadcast in the system information on the broadcast channel), and on transiting a Location Area (LA) or Routing Area (RA) boundary.

Location Updates are initiated from idle mode and are performed in order to keep the core network informed of the mobile's location for paging purposes. They are used either to update the LA within the VLR, or in the case of an update into a new MSC / VLR area, to inform the new VLR of its presence. This allows the new VLR to communicate with the mobile's Home Location Register (HLR) in order to retrieve the mobile's service profile and other required data. It also informs the HLR that the mobile is now located within the VLR area. This is used to route any incoming calls from the home network. The inter VLR handover case is shown opposite.

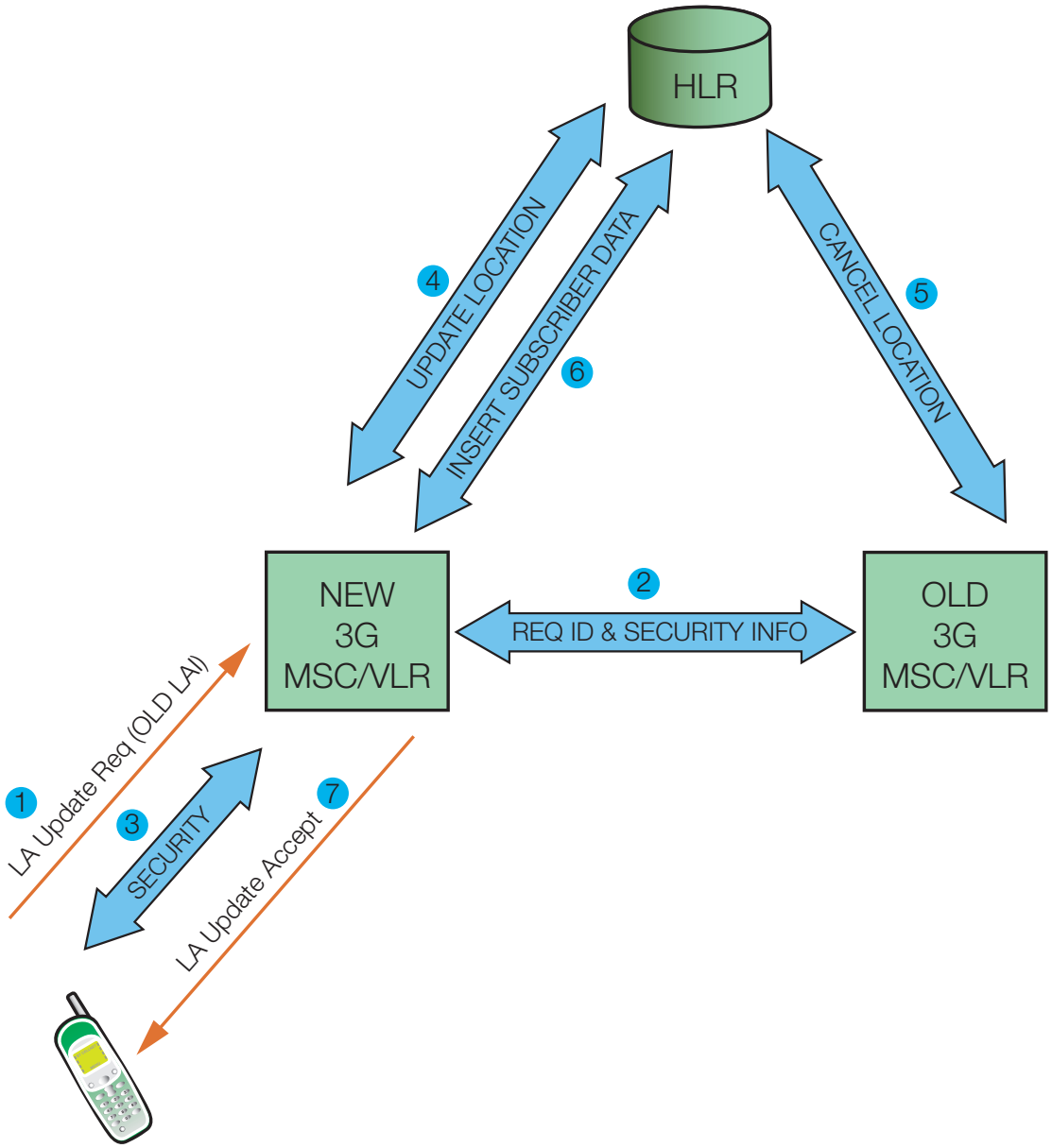
Routing Area Updates are very similar to Location Updates, but are relevant to the Serving GPRS Support Node. The RA is used as the update area. The SGSN either changes the RA for that mobile internally, or in cases of inter SGSN updates, the SGSN will contact the HLR to retrieve the subscriber data, and the Gateway GPRS Support Node (GGSN) to update any established contexts.

Combined Updates can be performed when either a UMSC (UMTS Mobile Switching Centre) is present, or an additional interface exists between the MSC / VLR and SGSN. The UMSC provides combined circuit switched and packet switched functionality. The updates can be within the UMSC or VLR and SGSN areas, or can be across areas.

In the case of a combined update into a new UMSC area, information is retrieved from the previous SGSN (or UMSC if applicable) whilst updating the context information. The UMSC then updates context information in the GGSN whilst contacting the HLR. The HLR cancels the location in the previous SGSN and VLR (or in the previous UMSC where applicable) before inserting the subscriber data into the new UMSC.

As in all location updates, the mobile is informed of the successful completion of the procedure before it falls back into the idle mode.

Example Location Update (other scenarios exist)



- RRC Connection is established before 1
- For Location update within same MSC/VLR area, delete 2, 4, 5 and 6.
- For RA update, the same basic procedure is followerd, replacing MSC/VLR with SGSN and changing Messages/Parameters.

Fig. 11 – Registration/Location Update (New MSC/VLR Area)

3.3 NAS Procedures Example – PDP Addresses & Context (Session Management)

In order to exchange data packets with external packet Data Networks (PDNs), following a successful attach to the UMTS network, a mobile station must apply for one or more addresses used in the PDN. These will be IP addresses if the external network is IP-based. These addresses are known as PDP (Packet Data Protocol) addresses.

PDP addresses may be static, in which case they are permanently assigned by the home network to the user. Or they may be dynamic, assigned as needed by the Home Operator or the Visited Operator. In the case of dynamic PDP addresses, the GGSN is responsible for the allocation and activation/deactivation of these addresses.

The PDP Context describes the characteristics of the session and contains:

- PDP type (e.g. IPv4)
- PDP address assigned to the mobile station
- requested QoS
- address of the GGSN which serves as the access point for the external PDN

This context is stored in the mobile station, the SGSN and the GGSN, and acts to make the mobile “visible” to the external PDN, and thus able to send and receive packets.

PDP Context:

- PDP Type
- PDP Address of UE
- Quality of Service
- GGSN Address

Fig. 12 – THE PDP Context

3.4 Call Set-up, Routing & Addressing

Using the example of an incoming call/data packet, it is possible to highlight the basic differences between providing a connection in the CS and PS domains.

1. CS Domain – establishing a circuit
In a fixed network, a terminal is semi-permanently wired to a central point, and a circuit-switched route can be directly established. However in mobile networks a user can roam. The number actually dialed for a subscriber in GSM Phase 2+ networks is called the Mobile Subscriber ISDN Number (MSISDN), and includes a country code and a code which identifies the subscriber's home operator.

An incoming call is directed to the Gateway MSC. The MSISDN number will enable this switch to identify and interrogate the subscriber's HLR. The HLR stores information regarding the subscriber's current MSC/VLR, including an address within the SS7 signalling system which is used to communicate with this entity. The HLR will obtain from this VLR a temporary Mobile Station Roaming Number, an internal network routing number which remains unseen by the user. This is passed back to the GMSC, and allows routing of the incoming call through to the appropriate Serving MSC, and the establishment of a circuit which then remains open for the duration of the call.

2. PS Domain Addressing & Routing
In the PS Domain, no permanent circuit is set up. Instead packets of data arriving from an external packet data network (PDN) are simply routed through to the mobile equipment as they arrive.

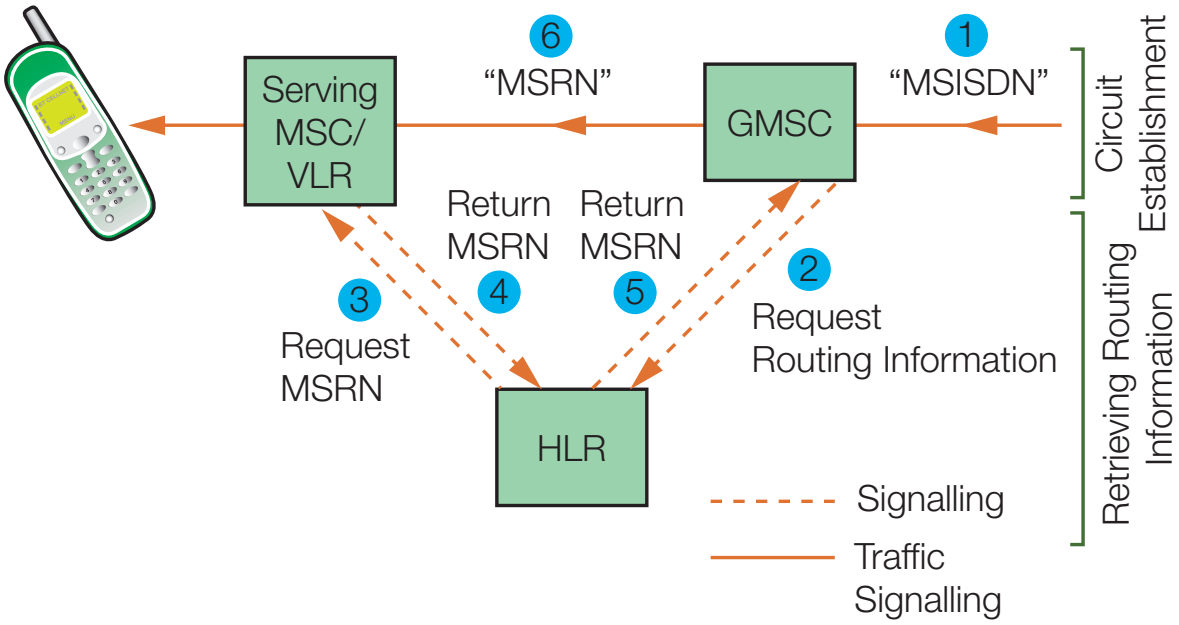
Taking the example of communication with an external IP network, hosts and routers in the PS domain require unique IP addresses. Indeed a router may have two or more addresses, since IP addresses do not specify computers but connections between computers and networks. Thus since a router connects at least two networks together, it will have an address relating to each connection.

In the UMTS context, this means that each SGSN and GGSN will have at least one IP address. This must be an IPv4 address, and may optionally also be an IPv6 address. These addresses will form part of a private address space (an Intranet), innaccessible directly from the public Internet.

In addition to routing between the nodes within the core network, the core network itself needs to facilitate and manage the establishment of an IP address for the mobile equipment, after which incoming data packets can be tunnelled directly to this address. To do this the GGSN may have to initially request the IP address of the current SGSN from the HLR. After this, further packets which form part of this "session" can be communicated directly to the SGSN, as can any further signalling processes.

These processes comprise **Session Management.**

CS Domain: establishing a circuit



PS Domain: establishing a route

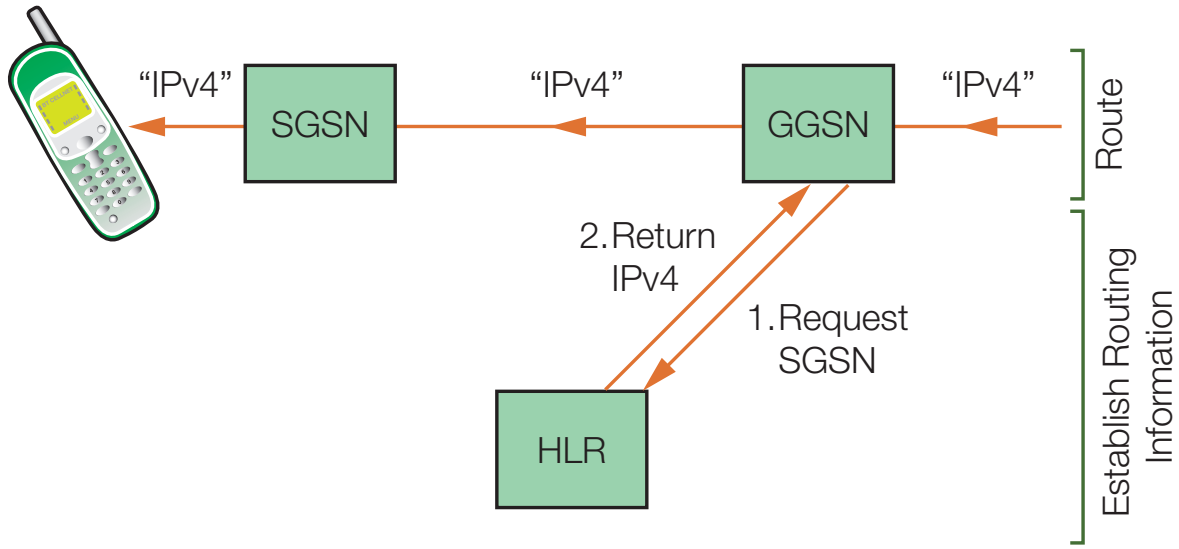


Fig. 13 – Routing and Addressing

3.5 CAMEL Interactions

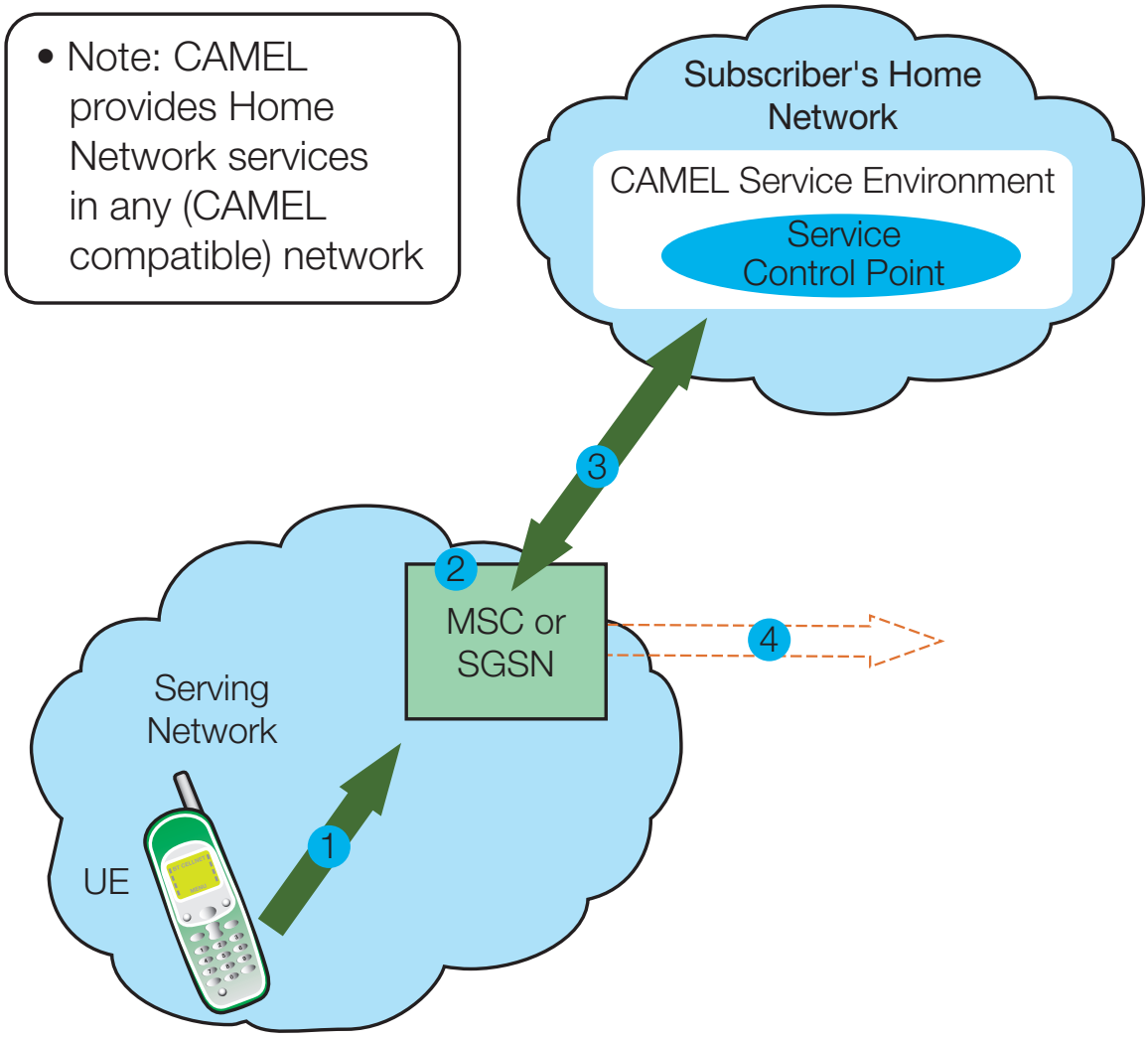
Customised Applications for Mobile Networks Enhanced Logic (CAMEL), is a network feature which allows operator specific services to be provided for mobiles even when “roaming” in other operator’s networks.

CAMEL is based on the Intelligent Network concept, which provides a toolkit of functionality rather than specifying a set of standard complete procedures.

A CAMEL modified MSC, SGSN, or UMSC is able to detect preconfigured triggers within control information. The triggers are included in the subscriber information sent to the serving VLR, SGSN or UMSC during the Location Update procedure. They can be as simple as triggering on any call or any series of address digits.

On encountering a trigger, the core network node will then send a message containing all relevant information to the mobile subscriber’s home network CAMEL Service Environment (CSE). This contains the Service Control Point which interacts with the core network node in the visited network to provide user interactions (announcements and voice responses), billing information, number translation, security functions etc.

CAMEL is applicable to procedures including packet switched or circuit switched procedures, location and routing update procedures, handovers, and short message transfer. It forms an integral part of the Virtual Home Environment (VHE) concept in UMTS.



1. UE & CN Interaction
2. Specified event(s) and data trigger CAMEL Interaction. May be CS or PS procedures, Location Update, Handover, Short Message Transfer etc.
3. CAMEL Interactions (Control of service by SCP in home network). May involve “user interactions”, number or address translation, billing information etc.
4. On completion of interaction, data transfer may be modified, billed or continue as required (if applicable)

Fig. 14 – CAMEL Interactions