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US 20060098574 A1

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(54) Abstract Title**: Buffering numbered unsegmented PDCP SDUs in 3GPP system to assist efficient hard handover**

(57) The invention buffers PDCP (Packet Data Convergence Protocol) SDUs (Service Data Unit) with sequence numbers before they are segmented into PDUs (Protocol Data Units), which may also be encrypted. The PDUs include references to the SDUs from which they were derived and are subject to an ARQ scheme. In this way when all the PDUs associated with an SDU have been acknowledged the SDU may be removed from the buffer. At the time of a hard handover the system allows unsent and unacknowledged SDUs to be forwarded easily to the new node. The system should minimise data loss while avoiding duplication of data sent over the air interface.

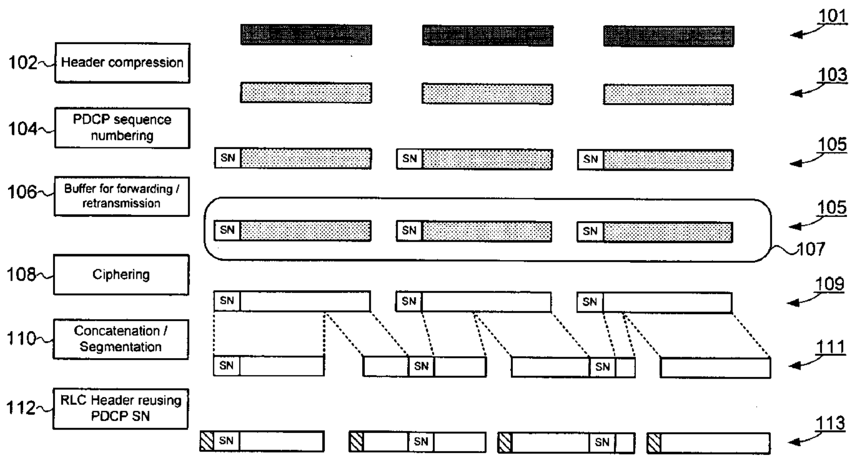

Figure 5

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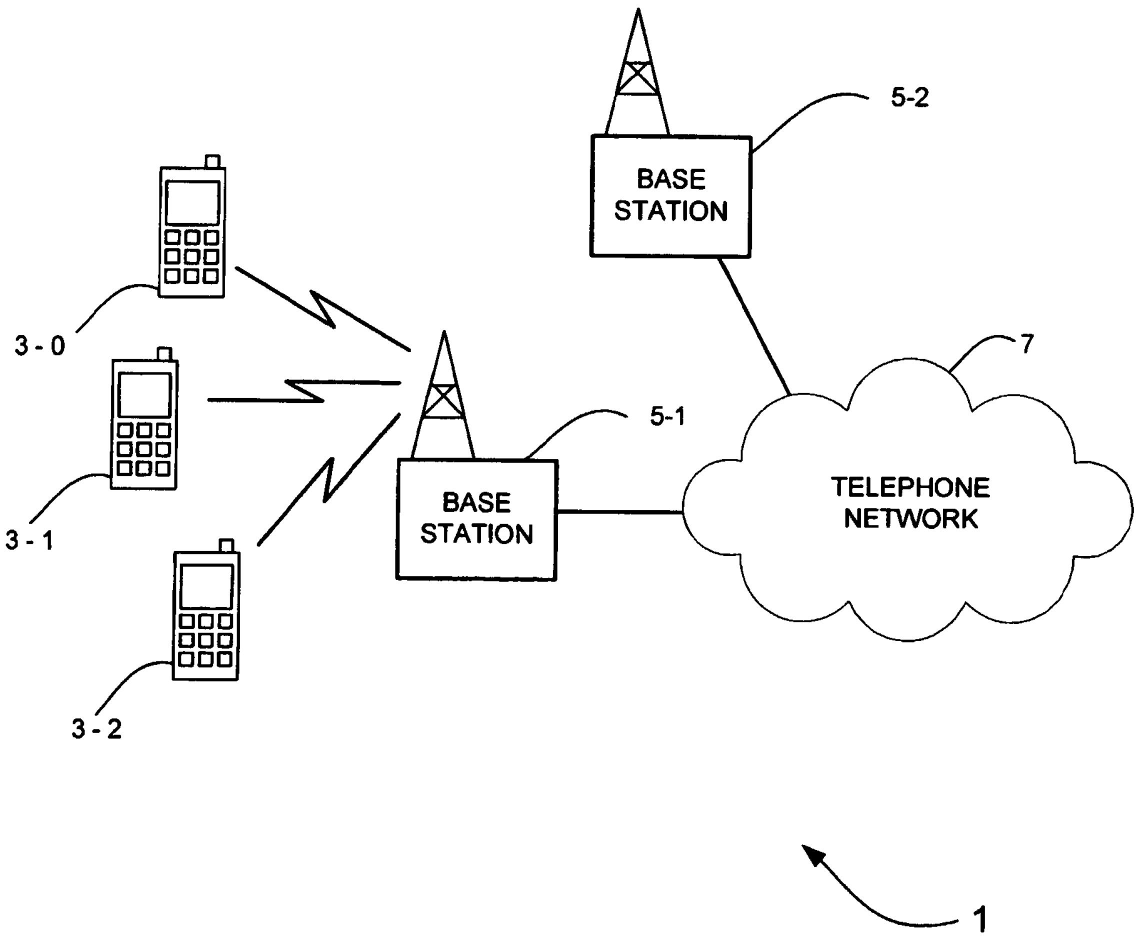

5-2
BASE
STATION
3 - 0
7
3 - 1
5-1
BASE
STATION
TELEPHONE
NETWORK
3 - 2
1

Figure 1

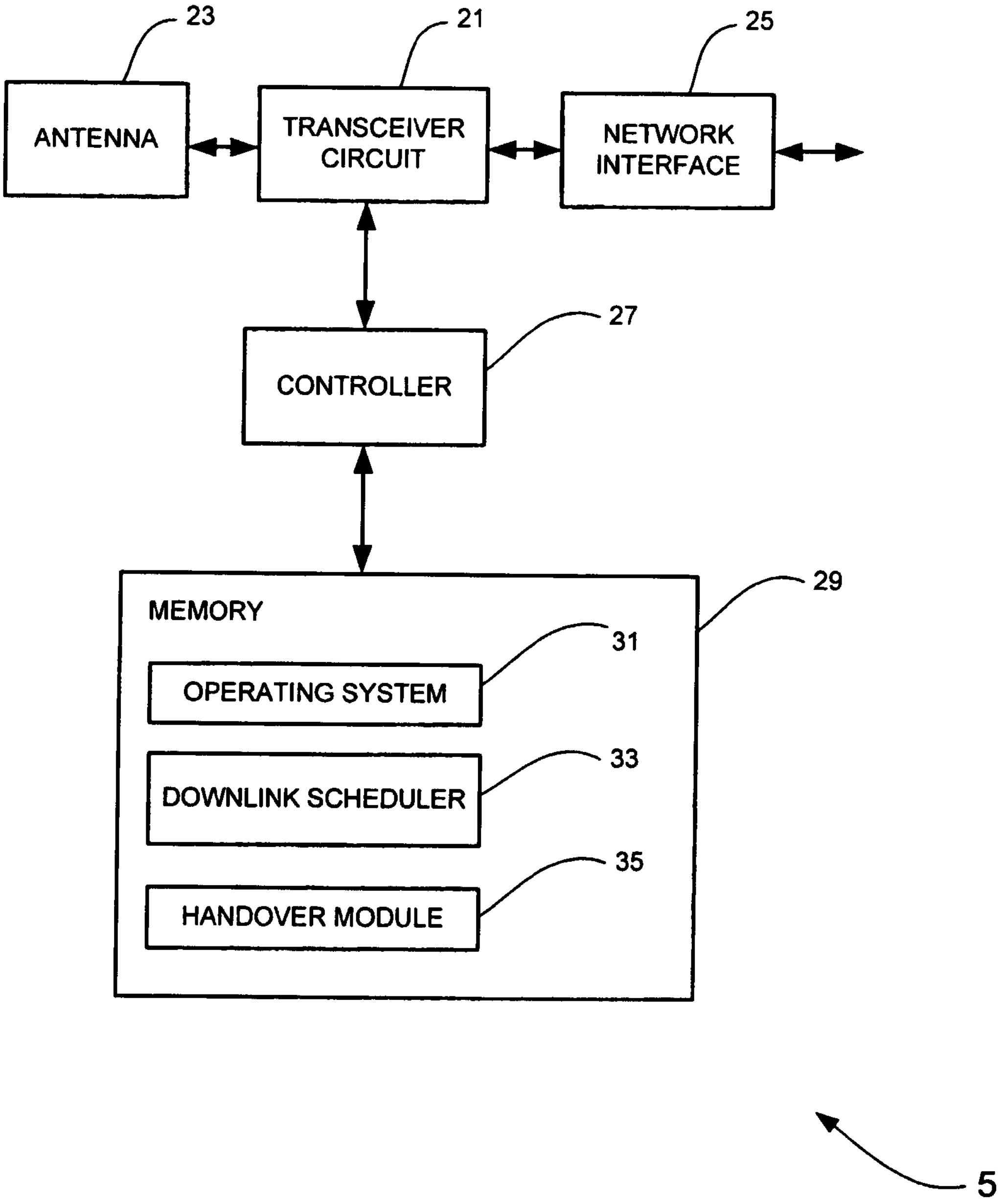

23
21
25
ANTENNA
TRANSCEIVER CIRCUIT
NETWORK INTERFACE
27
CONTROLLER
MEMORY
29
OPERATING SYSTEM
31
DOWNLINK SCHEDULER
33
HANDOVER MODULE
35
5

Figure 2

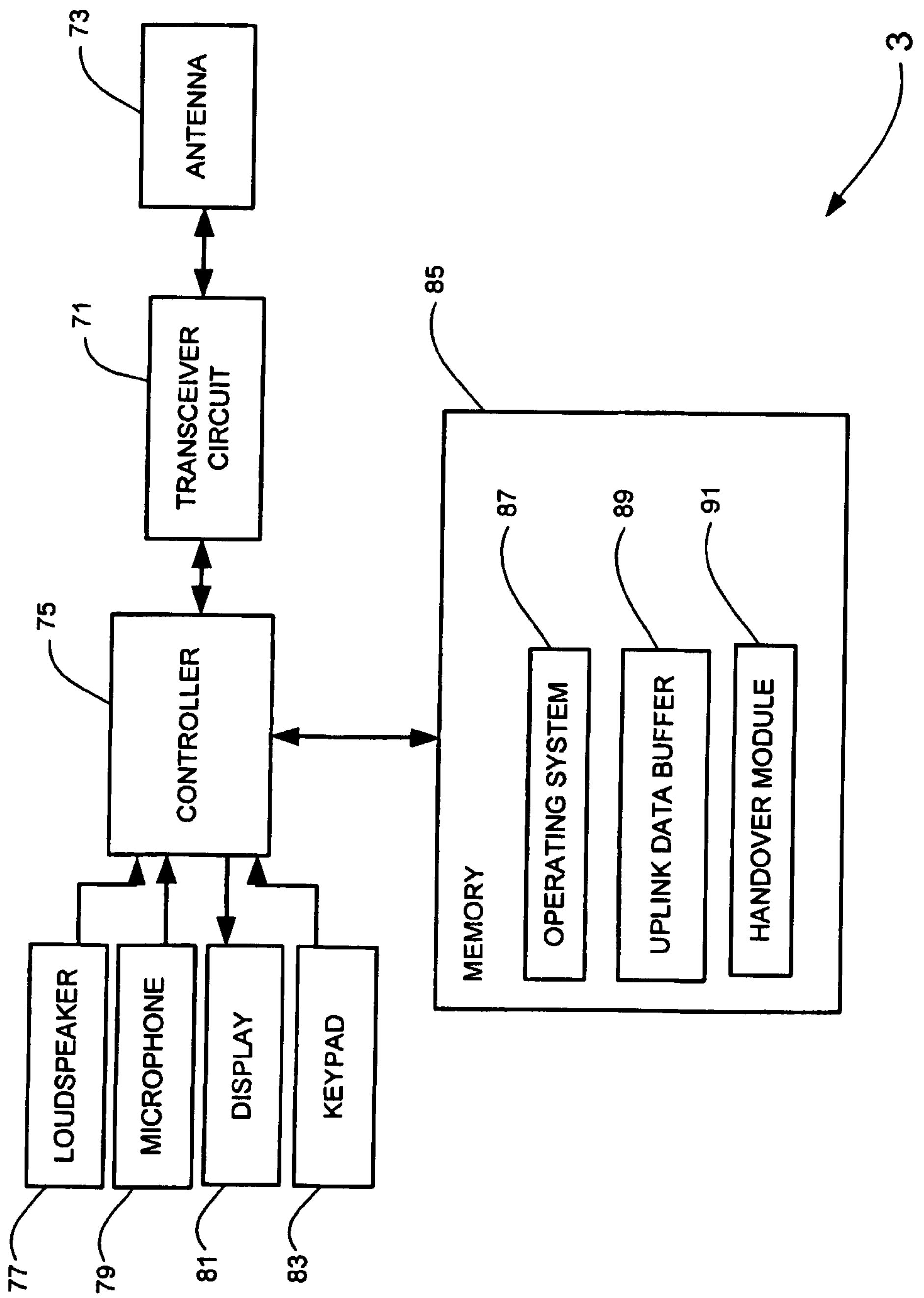

ANTENNA
73
TRANSCEIVER CIRCUIT
71
CONTROLLER
75
LOUDSPEAKER
77
MICROPHONE
79
DISPLAY
81
KEYPAD
83
MEMORY
85
OPERATING SYSTEM
87
UPLINK DATA BUFFER
89
HANDOVER MODULE
91
3

Figure 3

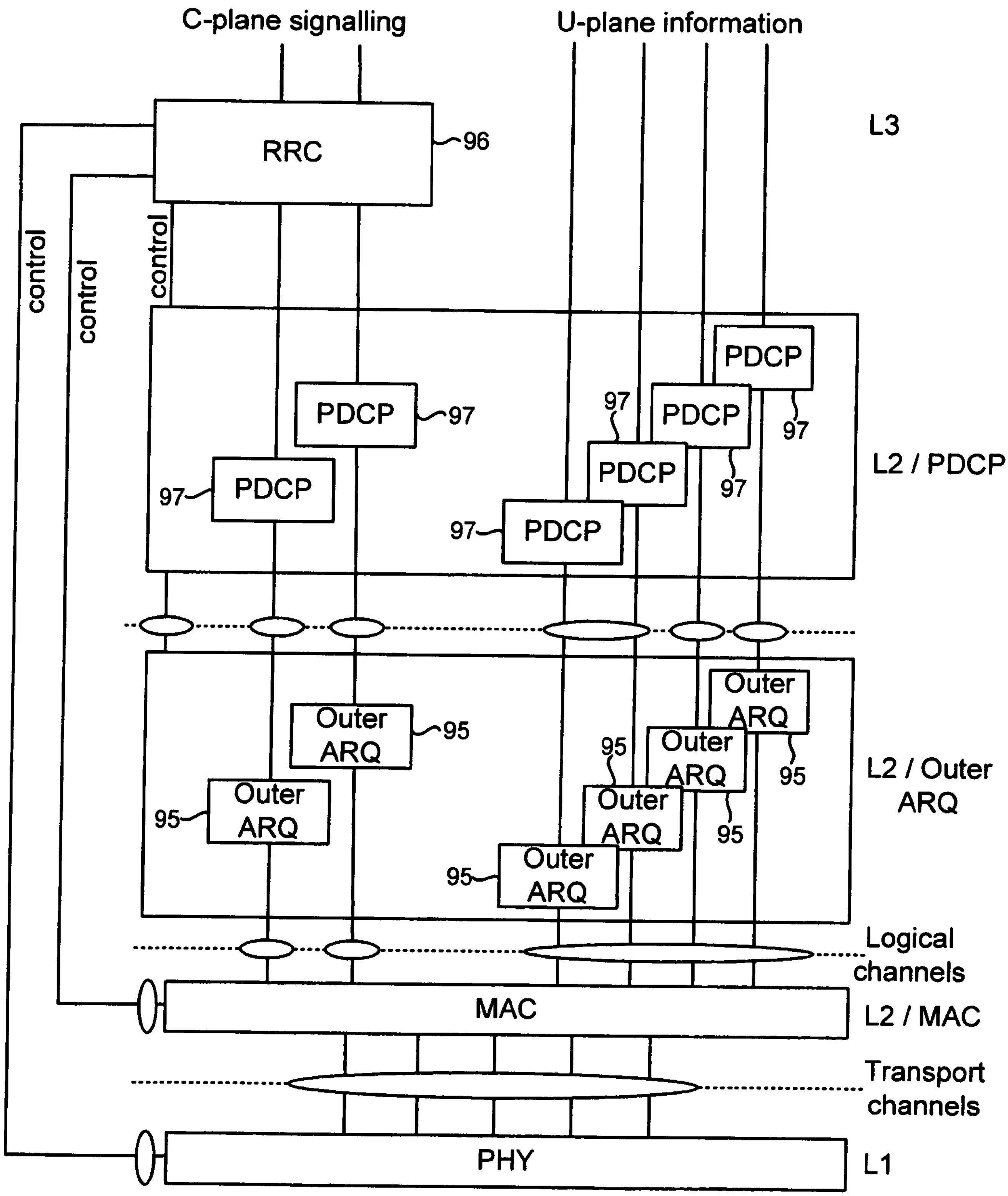
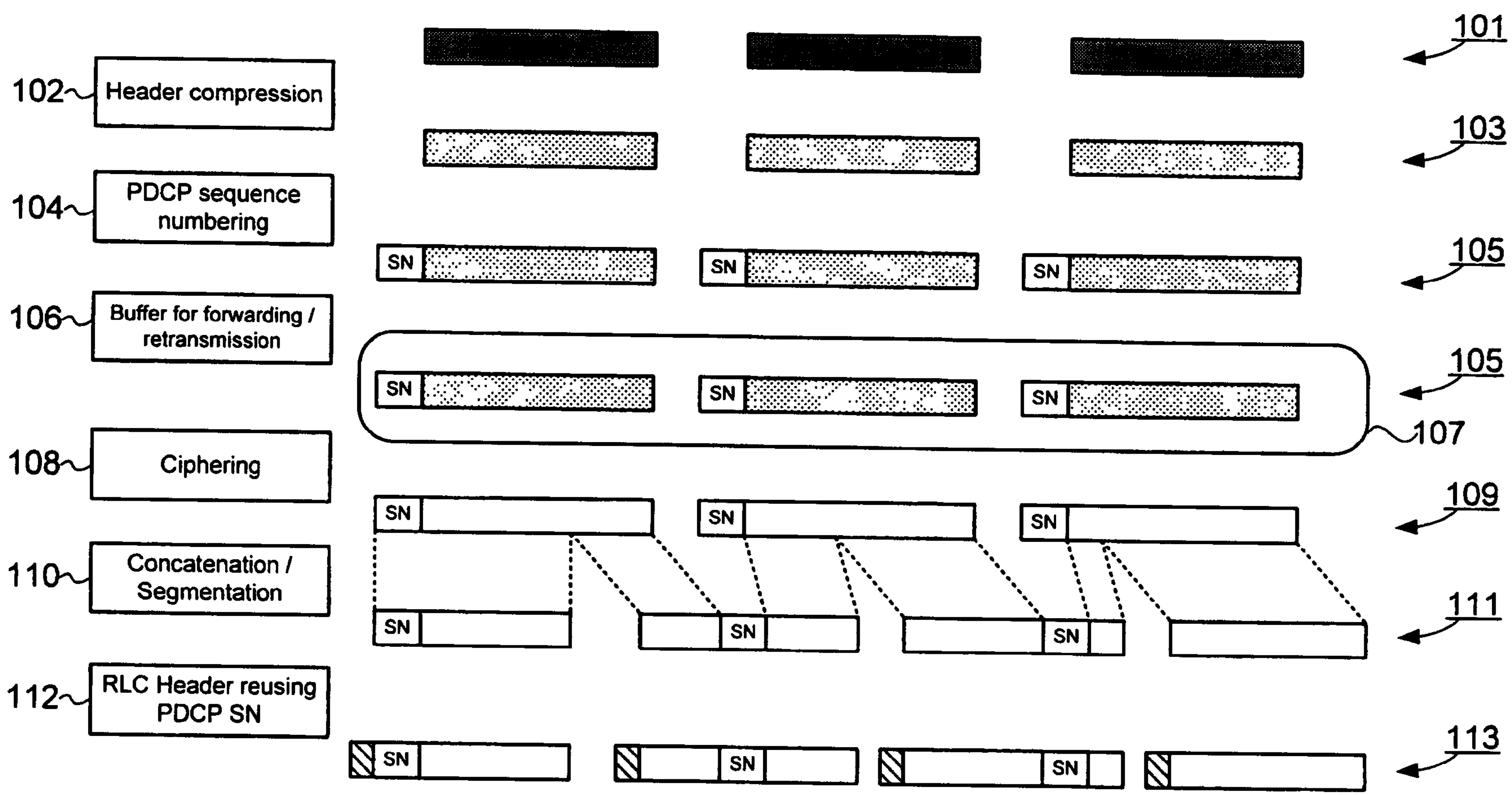

C-plane signalling
U-plane information
RRC
96
L3
control
control
control
PDCP
97
PDCP
97
PDCP
97
PDCP
97
PDCP
97
PDCP
97
L2 / PDCP
Outer ARQ
95
Outer ARQ
95
Outer ARQ
95
Outer ARQ
95
Outer ARQ
95
Outer ARQ
95
L2 / Outer ARQ
Logical channels
MAC
L2 / MAC
Transport channels
PHY
L1

Figure 4



102
Header compression
104
PDCP sequence numbering
106
Buffer for forwarding / retransmission
108
Ciphering
110
Concatenation / Segmentation
112
RLC Header reusing PDCP SN
SN
101
103
105
105
107
109
111
113

Figure 5

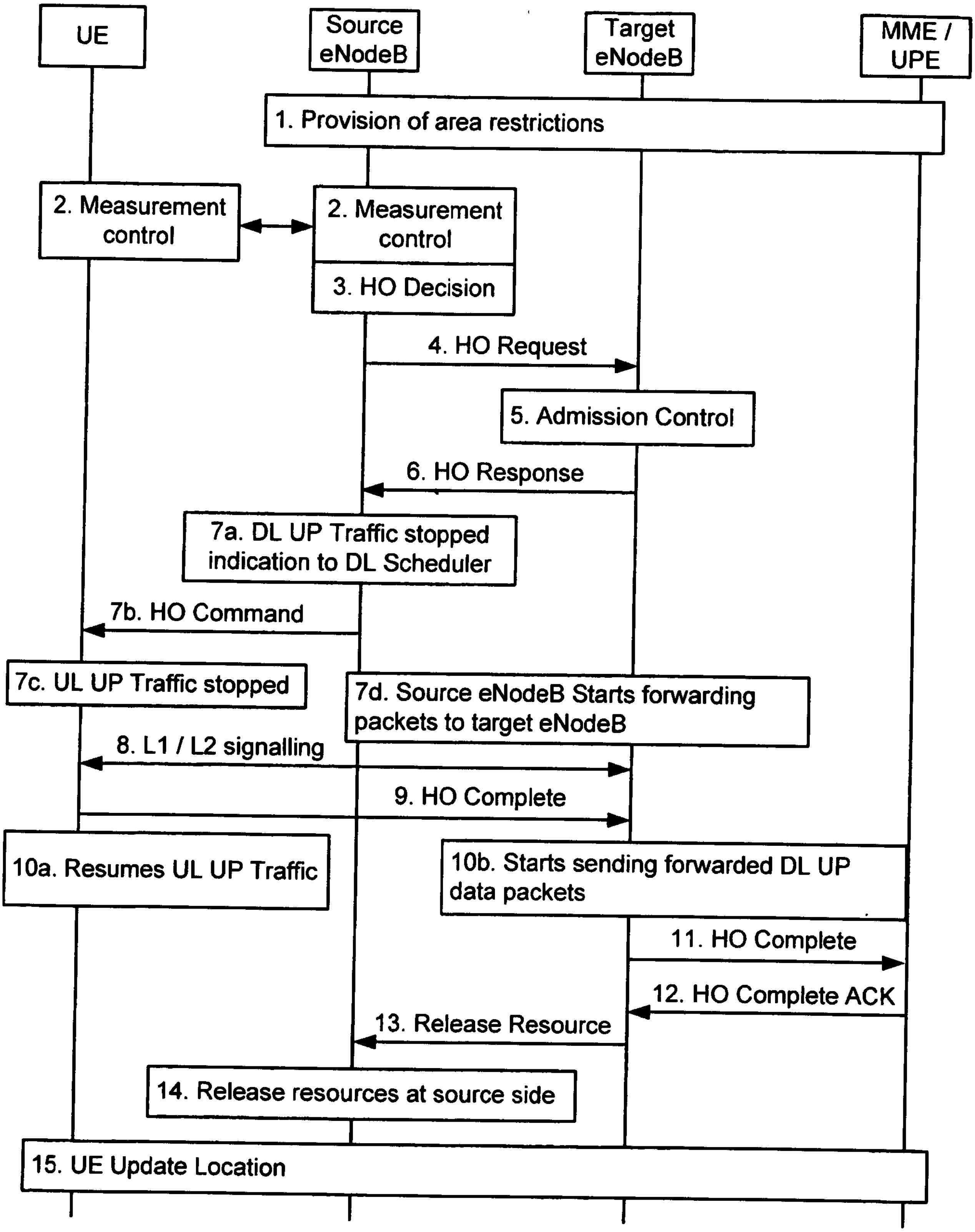

UE
Source eNodeB
Target eNodeB
MME / UPE
1. Provision of area restrictions
2. Measurement control
2. Measurement control
3. HO Decision
4. HO Request
5. Admission Control
6. HO Response
7a. DL UP Traffic stopped indication to DL Scheduler
7b. HO Command
7c. UL UP Traffic stopped
7d. Source eNodeB Starts forwarding packets to target eNodeB
8. L1 / L2 signalling
9. HO Complete
10a. Resumes UL UP Traffic
10b. Starts sending forwarded DL UP data packets
11. HO Complete
12. HO Complete ACK
13. Release Resource
14. Release resources at source side
15. UE Update Location

Figure 6

Handover Handling

The present invention relates to the management of data packets in mobile telecommunications networks, particularly but not exclusively networks operating according to the 3GPP standards or equivalents or derivatives thereof.

In mobile telecommunications networks, there is a requirement for User Equipment (UE) to handover from one base station to another. In the 3GPP, there has been recently proposed a procedure defined in the control plane (C-plane) for handover (HO) from a source eNodeB (base station) to a target eNodeB. The various acronyms applicable to 3G communications will of course be familiar to those skilled in the art but a glossary is appended for the benefit of lay readers.

Although for efficiency of understanding for those of skill in the art the invention will be described in detail in the context of a 3G system, the principles of handover can be applied to other systems, e.g. other CDMA or wireless in which a mobile device or User Equipment (UE) communicates with one of several other devices (corresponding to eNodeB) with the corresponding elements of the system changed as required.

At the RAN2/RAN3/SA2 joint meeting in St.Louis, the SAE/LTE architectural principles were agreed and the decision was to move the PDCP layer down to the eNodeB (base station). At the following RAN2 meeting in Malta it was decided that the ciphering would be performed at the PDCP layer using PDCP Sequence Numbers. Based on this decision user plane handling during handover needs further consideration and the present application proposes a suitable handover procedure.

According to one aspect, the present invention provides a communication method performed by a node of a telecommunication system, the method comprising:

receiving a sequence of PDCP Service Data Units, SDUs, for transmission to another communication node, such as a mobile device;

appending a sequence number to each PDCP SDU;

storing a copy of the PDCP SDUs with appended sequence number in a PDCP buffer;

ciphering the PDCP SDUs;

passing the ciphered PDCP SDUs with appended sequence numbers to an Outer ARQ entity for segmentation;

segmenting the ciphered PDCP SDUs with appended sequence numbers to generate Outer ARQ segments;

generating and appending a respective Outer ARQ header to each Outer ARQ segment to generate a corresponding Outer ARQ Protocol Data Unit, PDU, which header includes data identifying the position of the Outer ARQ segment within the corresponding PDCP SDU;

sending the generated Outer ARQ PDUs to the other communication node;

receiving acknowledgements for transmitted Outer ARQ PDUs; and

purging each PDCP SDU from the PDCP buffer once acknowledgements have been received for the Outer ARQ PDUs containing the PDCP SDU.

The method may be performed in a source node of the telecommunication system in which the other communication node is a mobile communication device and further comprising receiving a handover response from a target node and in response stopping transmission of data packets to the mobile communication device and forwarding PDCP SDUs with their appended sequence number stored in said PDCP buffer to the target node.

Preferably, the mobile communication device sends a status report to the ARQ entity of the source node, which identifies the sequence number of the last in-sequence PDCP SDU received and of any received out-of-sequence PDCP SDUs. The source node can then use this information to determine which PDCP SDUs stored in the PDCP buffer to send to the target node.

In one embodiment, out-of-sequence PDCP SDUs received from the other communication node are buffered and forwarded to the target node at handover.

Before being forwarded to the target node, the uplink PDP SDUs are marked to differentiate them from downlink PDCP SDUs.

According to another aspect, the invention provides a method of facilitating handover of a mobile communication device from a source node to a target node, the method being performed in the source node and comprising, in response to receiving a handover response from the target node:

stopping the transmission of downlink Outer ARQ PDUs from the source node to the mobile communication device;

transmitting a handover command to said mobile communication device after stopping the transmission of said downlink user data;

receiving a status packet from the mobile communication device, which status packet identifies the last in-sequence PDCP SDU received from the source node and any out-of-sequence PDCP SDUs received from the source node; and

forwarding PDCP SDUs to the target node in dependence upon the identified PDCP SDUs received by the mobile communication device.

The invention also provides a method of facilitating handover of a mobile communication device from a source node to a target node, the method being performed in the target node and comprising, in response to transmitting a handover response to the source node:

receiving forwarded downlink PDCP SDUs from the source node;

receiving forwarded uplink out-of-sequence PDCP SDUs from the source node;

transmitting Outer ARQ PDUs corresponding to the received downlink PDCP SDUs to the mobile communication device;

receiving Outer ARQ PDUs from the mobile communication device and forming from them corresponding PDCP SDUs with sequence numbers; and

reordering the received PDCP SDUs and the forwarded PDCP SDUs based on their sequence numbers and forwarding them in sequence to a telecommunication network.

The invention still further provides a method performed by a mobile communication device at handover from a source node to a target node, the method comprising:

receiving a status packet from the source node identifying the last in-sequence uplink PDCP SDUs received by the source node and any out-of-sequence PDCP SDUs received by the source node;

receiving a handover command from the source node;

transmitting a status packet to the source node identifying the last in-sequence downlink PDCP SDU received from the source node and any out-of-sequence PDCP SDUs received from the source node;

stopping transmission of data packets to the source node;

establishing a communication link with the target node;

determining PDCP SDUs to be transmitted/retransmitted to the target node based on the status packet received from the source node; and

transmitting/retransmitting the determined PDCP SDUs to the target node.

While the invention is described for ease of understanding in the context of handover from one 3G eNodeB to another, the principles may be extended to handover between nodes of different networks, e.g. a 3G network and another network.

The invention provides, for all methods disclosed, corresponding computer programs or computer program products for execution on corresponding equipment, the equipment itself (user equipment, nodes or components thereof) and methods of updating the equipment.

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 schematically illustrates a mobile telecommunication system of a type to which the embodiment is applicable;

Figure 2 schematically illustrates a base station forming part of the system shown in Figure 1;

Figure 3 schematically illustrates a mobile communication device forming part of the system shown in Figure 1;

Figure 4 illustrates part of a protocol stack forming part of the communication software used to control communications between the mobile communication device and the base stations;

Figure 5 shows a handover process;

Figure 6 illustrates the operation of the PDCP and outer ARQ entities for managing the buffering of acknowledge mode data packets.

Overview

Figure 1 schematically illustrates a mobile (cellular) telecommunication system 1 in which users of mobile telephones (MT) 3-0, 3-1, and 3-2 can communicate with other users (not shown) via one of the base stations 5-1 or 5-2 and a telephone network 7. In this embodiment, the base stations 5 use an orthogonal frequency division multiple access (OFDMA) technique in which the data to be transmitted to the mobile telephones 3 is modulated onto a plurality of sub-carriers. Different sub-carriers are allocated to each mobile telephone 3 depending on the amount of data to be sent to the mobile telephone 3. When a mobile telephone 3 moves from the cell of a source base station (eg base station 5-1) to a target base station (eg base station 5-2), a handover (HO) procedure (protocol) is carried out in the source and target base stations 5 and in the mobile telephone 3, to control the handover process.

The handover process aims to provide an optimised hard handover (HHO) between the source and target base stations 5 with the following requirements:

1. Lossless HHO for the non-real time (NRT) Services in order achieve high TCP throughput performance.
2. Seamless HHO for real time (RT) services to minimise the packet loss in order to have good end to end performance of the application.
3. Minimization of duplicate packet transmission over the air interface.
4. Minimal interruption time for the user plane data.
5. In sequence delivery of NAS (Non Access Stratum) PDUs should be maintained during HO.

6. No duplication and out of sequence delivery should be visible to ROHC (Robust Header Compression) and application.

A hard handover is one where there is a break in radio transmissions between the mobile telephone and the base stations during the handover, as opposed to a soft handover, where the mobile telephone will establish a radio link with both the source and target base stations during the handover procedure. As those skilled in the art will appreciate, it is therefore more difficult to perform a hard handover whilst minimising packet loss and packet retransmission.

Base Station

Figure 2 is a block diagram illustrating the main components of each of the base stations 5 used in this embodiment. As shown, each base station 5 includes a transceiver circuit 21 which is operable to transmit signals to and to receive signals from the mobile telephones 3 via one or more antennae 23 (using the above described sub-carriers) and which is operable to transmit signals to and to receive signals from the telephone network 7 via a network interface 25. A controller 27 controls the operation of the transceiver circuit 21 in accordance with software stored in memory 29. The software includes, among other things, an operating system 31 and a downlink scheduler 33. The downlink scheduler 33 is operable for scheduling user data packets to be transmitted by the transceiver circuit 21 in its communications with the mobile telephones 3. The software also includes a handover module 35, the operation of which will be described below.

Mobile Telephone

Figure 3 schematically illustrates the main components of each of the mobile telephones 3 shown in Figure 1. As shown, the mobile telephones 3 include a transceiver circuit 71 that is operable to transmit signals to and to receive signals from the base station 5 via one or more antennae 73. As shown, the mobile telephone 3 also includes a controller 75 which controls the operation of the mobile telephone 3 and which is connected to the transceiver circuit 71 and to a loudspeaker 77, a microphone 79, a display 81, and a keypad 83. The controller 75 operates in accordance with software instructions stored within memory 85. As shown, these software instructions include, among other things, an operating system 87. In this embodiment, the memory also provides uplink data buffers 89. The software for controlling the handover process is provided by a handover module 91, the operation of which will be described below.

In the above description, both the base station 5 and the mobile telephones 3 are described for ease of understanding as having respective discrete handover modules which control the handover procedure when a mobile telephone 3 moves from a source base station to a target base station. Whilst the features may be provided in this way for certain applications, for example where an existing system has been modified to implement the invention, in other applications, for example in systems designed with the inventive features in mind from the outset, the handover features may be built into the overall operating system or code and so a handover module as a discrete entity may not be discernible.

Operation

The following description will use the nomenclature used in the Long Term Evolution (LTE) of UTRAN. Therefore, the mobile telephone 3 that is changing base stations will be referred to as a UE, the source base station 5-1 will be referred to as the source eNodeB and the target base station 5-2 will be referred to as the target eNodeB. The protocol entities used in LTE have the same names as those used in UMTS except for the Radio Link Control (RLC) entities which, under LTE, are called the Outer ARQ entities. The Outer ARQ entities of LTE have substantially the same (although not identical) functionality to the RLC entities of UMTS.

Figure 4 illustrates part of a protocol stack (lower three layers) used in the UE and eNodeBs. The first layer is the physical layer (L1) which is responsible for the actual transmission of the data over the radio communication channel. Above that is the second layer (L2), which is divided into three sub-layers – the Medium Access Control layer (L2/MAC) which is responsible for controlling access to the air interface; the Outer ARQ layer (L2/OARQ) which is responsible for concatenation and segmentation of data packets, the acknowledgment of packets and the re-transmission of data packets where necessary; and the PDCP layer (L2/PDCP) which is responsible for header compression and ciphering. Above the second layer is the Radio Resource Control (RRC) layer (L3/RRC) that is responsible for controlling radio resources used in the air interface between the eNodeB and the UE. As shown, the L2/Outer ARQ layer includes a number of Outer ARQ entities 95 used to manage the transmission of C-plane data and U-plane data and the L2/PDCP layer includes PDCP entities 97 used to process the C-plane and the U-plane data.

Figure 5 schematically illustrates the operations performed by the PDCP entities 97 and the Outer ARQ entities 95 when processing downlink data packets. A similar process is performed for uplink data packets, but in the reverse order. As shown, PDCP SDUs 101 received by the PDCP entity 97 firstly undergo a header compression 102 to generate corresponding SDUs 103 with compressed headers. The PDCP entity 97 then generates and appends 104 a sequence number (SN) to each SDU 103 identifying the number of the SDU in the sequence of SDUs for the UE. The thus generated SDUs with SNs 105 are then buffered 106 in a PDCP buffer 107. These SDUs are then ciphered 108 to generate the ciphered PDCP PDUs 109, which are passed to the Outer ARQ entity 95, where they are segmented to form Outer ARQ SDU segments 111. Each Outer ARQ SDU segment is then tagged with data identifying the segment and its position within the corresponding PDCP PDU 109. In this embodiment, the Outer ARQ entity 95 reuses the PDCP sequence number (SN) and an OFFSET and LENGTH which indicate the position and length of the Outer ARQ segment in the original PDCP PDU 109.

During normal operation, for downlink AM packets, the PDCP entity 97 will purge each PDCP SDU 105 from its buffer 107 as soon as the Outer ARQ entity 95 confirms that it has received acknowledgements for all the Outer ARQ segments 111 that contain the PDCP SDU 105. For downlink UM packets, the PDCP entity 97 deletes each PDCP SDU 105 from its buffer 107 as soon as the Outer ARQ entity 95 acknowledges the transmission of the Outer ARQ PDUs 111 containing the PDCP SDU 105. For uplink AM packets, the outer ARQ entity 95 receives packet segments from the UE and acknowledges receipt. The Outer ARQ entity 95 then concatenates the received packet segments to generate ARQ SDUs which it forwards to the PDCP entity 97. The PDCP entity 97 then deciphers the received ARQ SDUs and if the sequence number is not out of sequence, it removes the SN and decompresses the header before forwarding the packet to an MME/SAE Gateway in the telephone network 7. However, if the received packet is out of sequence, then the PDCP entity 97 stores the received packet in its buffer 107, until all the missing packets have been received at which point the PDCP entity 97 reorders the SDUs based on their PDCP sequence numbers, then removes the SN, decompresses the packet headers and forwards the received packets in correct sequence to the telephone network 7. For uplink UM packets, the Outer ARQ entity 95 receives the packet segments, concatenates them and sends them to the PDCP entity 97. The PDCP entity 97 then deciphers the packets, removes their sequence numbers, decompresses their headers and then forwards them to the telephone network 7.

Description of the Handover protocol

The description that follows mainly applies to acknowledge mode (AM) Radio Link Control (RLC), in which receipt of data packets are acknowledged by the receiver, although the Outer ARQ entity (the equivalent of RLC for LTE) may not be identical to the RLC in all aspects. Specifics of unacknowledged mode (UM) Outer ARQ entities employed for real time applications such as VoIP and streaming are also brought out wherever there is a different handling applied as compared to the acknowledge mode entities.

In order to transfer the context and forward the data to support lossless inter eNodeB handover, we have appreciated that it is desirable that the source eNodeB is able to synchronize the data transmission status between itself and the target eNodeB during handover. From this we have concluded that the data flow should desirably be stopped at an appropriate instant in time during the handover execution phase considering that the interruption time for the User Plane data is minimal. However, fulfilling this desired requirement is not straightforward as stopping the data transmission through additional signalling would be problematic as it would increase the overall handover time. We have appreciated that it is possible implicitly to stop the data transmission in (one or both, preferably both) the source eNodeB and UE at the time of handover execution, by modifying the conventional approach (which is carried out solely in the C-plane) to build in some "realisation" of the handover process in the User plane data transfer process. A further desirable feature is that the number of duplicated packets transmitted over the air either by the target eNodeB or by the UE is minimised.

Figure 6 shows timings when it is proposed to stop the U-plane data transmission in the Downlink (DL) and the Uplink (UL), together with the details of the modified sequences described. The following description explains how this approach of stopping the data flow facilitates achieving a fast lossless handover for LTE.

Referring to Figure 6, information flow for Intra-LTE-Access Mobility Support is described.

1) The UE context within the source eNodeB contains information regarding roaming restrictions which were provided either at connection establishment or at the last TA update.
2) The source eNodeB entity configures the UE measurement procedures according to the area restriction information. Measurements provided by the source eNodeB entity may assist the function controlling the UE's connection mobility.
3) Based on measurement results from the UE and the source eNodeB, probably assisted by additional RRM specific information, the source eNodeB decides to handover the UE to a cell controlled by the target eNodeB.
4) The source eNodeB issues a handover Request to the target eNodeB entity passing necessary information to prepare the handover at the target side. The target eNodeB configures the required resources.
5) Admission Control is performed by the target eNodeB to increase the likelihood of a successful handover, if the resources can be granted by target eNodeB.
6) The handover preparation is finished at the target eNodeB, information for the UE to reconfigure the radio path towards the target eNodeB is passed to the source eNodeB.
7) This step consists of the following sub steps.
    a. Before submitting the HO Command to the lower protocol layers, the Radio Resource Control (RRC) entity 96 in the source eNodeB commands the Outer ARQ User Plane (UP) entities 95 to send a status

packet in the downlink direction and stop the DL transmission so that these Outer ARQ entities 95 shall not submit any Outer ARQ PDUs to the lower protocol layer. The UL reception should continue. In case receiving packets are UM Outer ARQ PDUs, the Outer ARQ entity will reassemble the SDUs and transfer them to the upper layers as soon as all PDUs that contain the SDU have been received.

b. The UE is commanded by the source eNodeB RRC entity 96 to perform the HO; target side radio resource information is contained in the command.

c. On receiving the HO Command the RRC entity 96 in the UE commands the outer ARQ U-plane entities to send a status packet in the Uplink direction and stop the UL transmission. In response, the PDCP layer in the source eNodeB positively purges the corresponding PDCP SDU from its buffer 107. Following this, the UE shall immediately initiate the L1/L2 signalling in the target eNodeB after this.

d. Since the user plane data transmission is stopped in both directions and the status packet exchanged in both uplink and downlink, the source eNodeB will be able to accurately synchronize the data transmission status between source and target eNodeBs, and SDU forwarding (from Source eNodeB to target eNodeB) can start from any point after this.

8) The UE gains synchronisation at the target side.

9) Once the UE has successfully accessed the cell, it sends an indication to the target eNodeB that the handover is completed.

10 a) After submitting the handover Complete to the lower layer, the RRC entity 96 in the UE commands the PDCP entities 97 and the Outer ARQ entities 95 to resume the UL U-plane traffic.

10 b) On reception of handover Complete, the RRC entity 96 in the target eNodeB commands the PDCP entities 97 and the Outer ARQ U-plane entities 95 to resume the DL traffic. The target eNodeB starts the transmission of the forwarded DL packets received from the source eNodeB.

11) The MME/UPE is informed that the UE has changed cell. The UPE switches the data path to the target eNodeB and can release any U-plane/TNL resources towards the source eNodeB.

12) The MME/UPE confirms the handover Complete message to the target eNodeB with the handover Complete ACK message.

13) The target eNodeB triggers the release of resources at the source side. The target eNodeB can send this message directly after reception of message 9.

14) Upon reception of the Release Resource message, the source eNodeB releases radio and C-plane related resources in relation to the UE context. The source eNodeB continues to perform data forwarding until an implementation dependent mechanism decides that data forwarding can be stopped and U-plane/TNL resources can be released.

15) If the new cell is a member of a new Tracking Area, the UE needs to register with the MME/UPE which in turn updates the area restriction information on the target eNodeB.

Unidirectional stopping of the Outer ARQ entities

Since data transmission is being stopped in the source eNodeB and in the UE at the time of handover execution, it needs to be emphasised that suspending the user plane data transfer in both directions (as in a conventional REL 6 RLC entity) would result in data loss as the data packets in flight will be discarded by the RLC entity that has been stopped. Hence for a LTE system where there will be hard handovers, the outer ARQ entity (RLC) should stop transmissions but continue to receive packets to avoid any data loss.

Packet forwarding

In this embodiment, the PDCP sequence numbers are maintained during handover (used by the target eNodeB) and the source eNodeB selectively forwards all downlink PDCP SDUs (with SN) 105 (from the buffer 107) that have not been acknowledged by the UE to the target eNodeB, and discards any remaining downlink Outer ARQ PDU segments that have not yet been transmitted. During handover, the source eNodeB also forwards uplink PDCP SDUs 105 successfully received in-sequence to the telephone network 7 (SAE Gateway), forwards uplink PDCP SDUs 105 received out-of-sequence, from the buffer 107, to the target eNodeB and discards any remaining uplink Outer ARQ PDUs. The uplink PDCP SDUs received out-of-sequence need to be marked as Uplink Packets by the PDCP entity 97 before they are forwarded to the target eNodeB

PDCP entity 97 so that the target eNodeB can establish that the packet is an out-of-sequence uplink packet and not a downlink packet for transmission to the UE. The target eNodeB PDCP then forwards these out-of-sequence uplink packets to the telephone network 7 once the missing uplink packets have been received from the UE.

Sending STAUS PDU before stopping the Outer ARQ entities

In order to transfer the context and forward the data to support lossless inter eNodeB HO, the source eNodeB synchronizes the data transmission status between itself and the UE with the target eNodeB during HO. This is facilitated by stopping the data flow at an appropriate instant in time during the HO execution phase, considering that the interruption time for the user plane data is minimal. In one embodiment the Outer ARQ entity in the source eNodeB and in the UE sends the other a status report (indicating what that device has received successfully) before stopping the data flow in the appropriate direction. This status message may be a simplified report indicating only what the device has received. This allows the source eNodeB and the UE to get to know the exact data transmission status (ie what the other party has received and therefore what still has to be sent) before stopping the transmission during the HO execution. Therefore, after the HO the data transmission can resume without the need to transmit any duplicated packets over the air interface.

In the preferred embodiment, the Outer ARQ status reports exchanged at the time of handover are based on the Outer ARQ SDUs 109 using the PDCP sequence numbers (SNs), rather than status reports based on the Outer ARQ PDUs 111, as these would have to be larger in size (to include the PDCP SN as well as the OFFSET and LENGTH data which are needed to identify each Outer ARQ PDU 111) and may delay the handover. With PDCP SN based Status Reports, the size of the Status PDU can be reduced to an order of tens of bytes, facilitating fast transmission at the time of handovers. During normal operation, the Outer ARQ entities may exchange status PDUs based on the smaller sized ARQ PDUs. Unlike the status PDUs used during handover, these status PDUs will include the OFFSET and LENGTH data needed to identify the smaller ARQ PDUs.

Advantages

The precise timings that are indicated above for stopping the data flow help in meeting the following (separate) desiderata we have formulated.

I. Unified Lossless handover mechanism for both real-time and non real-time services

II. Minimal interruption time for the user plane data.

III. Minimising transmission of duplicate packets by eNodeB and UE.

Desideratum I is met by having PDCP entities 97 which are capable of buffering and forwarding the DL data packets form source to target eNodeB. In the UE the PDCP entities 97 may buffer the data packets generated by the application after the UL transmission is stopped until the UE is switched to the target eNodeB – this requires the UE to provide buffering not present in a conventional UE, but this may not be unduly problematic to implement. By implicitly stopping the data flows the source eNodeB can synchronize the data transmission status between source and target eNodeB. This is because the source eNodeB can know accurately which are the PDCP SDUs that need to be transferred to the target eNodeB based on the data in the transmission and retransmission buffer.

Regarding the desideratum II, since there is no explicit (additional) signalling involved for stopping the data flow in the UL as well as the DL directions, there will be no increase in the interruption time for the user plane data.

Furthermore, the instance when the DL data is stopped is chosen to be most optimal according to our considerations so as to have minimum interruption time. If the source eNodeB continues to schedule DL data, the UE will not be able to successfully receive or acknowledge these data packets as, immediately after receiving the handover command, it would try to synchronise with the target cell. Eventually these packets would have to be forwarded to the target eNodeB and will have to be transmitted again through the target eNodeB resulting in inefficient usage of the air interface bandwidth. Whilst according to conventional thinking it might be argued that for real-time services such as VoIP, stopping the data would be detrimental to the service, we have appreciated that if the source eNodeB continues to transmit DL packets there is no mechanism by which they could be recovered if the UE could not receive them while it is trying to synchronise with the target cell and this might, in practice, be at least as problematic. However we have appreciated that if the data flow is stopped and a packet forwarding mechanism is adopted, there is a possibility to eliminate packet loss in the DL, although there could be a delayed data packet delivery to the UE which could result in just a single packet being discarded in the worst case. But this could be compensated through the play-out buffer.

Similarly if the UE continues to transmit in the UL while trying to gain synchronisation with the target cell, it may not be able to receive acknowledgements from the source eNodeB and the UE would have to again transmit these AM packets in the UL direction to the target eNodeB resulting in inefficient usage of the air interface bandwidth. For real time (RT) services, packets that are transmitted in the UL direction by the UE while it is trying to gain synchronisation in the target eNodeB, may get lost due to bad radio conditions in the UL and could not be recovered if the data flow is not stopped. Hence it would be beneficial to avoid any packet loss even for real time services in the UL by stopping the UL data flow during handover execution while the delay could be compensated at the receiving end by the play out buffer.

Furthermore if the transmission of data continues both in the UL and DL directions after the handover Command is sent by the source eNodeB, it would be complicated to synchronize the data transmission status between source and target eNodeBs because of the dynamic nature of the packets in the transmission and retransmission buffers at the source eNodeB and would result in duplicated packets being transmitted again by the target eNodeB in the DL and by the UE in the UL to ensure lossless handover for non-real time (NRT) Services resulting in inefficient usage of the air interface bandwidth. However, for real-time services such as VoIP etc using UM mode, data packets transmitted by the source eNodeB and not received correctly at the target eNodeB, will be lost and cannot be recovered. Hence stopping the data flow for both RT and NRT services in a unified way will help in better resource utilization on the air interface for the NRT Bearers and will avoid data loss for RT services.

Another advantage of having a definitive time instant for stopping the data flow is that a simplified implicit reordering of the data packets in the target eNodeB can be achieved if the forwarded DL data packets from the source eNodeB on the X2 interface are transmitted first to the UE followed by the data received from the telephone network 7 (MME/SAE Gateway on the S1 interface).

From the above discussion it seems desirable to stop the UL and DL data transmission during the handover execution for both RT and NRT Services to support lossless Inter eNodeB handover, while aiming to keep the interruption time and transmission of duplicate packets to a minimum.

Glossary of 3GPP terms
LTE – Long Term Evolution (of UTRAN)
eNodeB – E-UTRAN Node B
AGW – Access Gateway
UE – User Equipment – mobile communication device
DL – downlink – link from base to mobile
UL – uplink – link from mobile to base
AM – Acknowledge Mode
UM – Unacknowledge Mode
MME – Mobility Management Entity
UPE- User Plane Entity
HO – Handover
RLC – Radio Link Control
RRC – Radio Resource Control
RRM – Radio Resource Management
SDU – Service Data Unit
PDU – Protocol Data Unit
NAS – Non Access Stratum
ROHC – Robust Header Compresion
TA - Tracking Area
U-plane - User Plane
TNL – Transport Network Layer
S1 Interface – Interface between Access Gateway and eNodeB

X2 Interface – Interface between two eNodeB

MMEs / SAE Gateway – New name for Access Gateway having both MME and UPE entities

The following is a detailed description of the way in which the present inventions may be implemented in the currently proposed 3GPP LTE standard. Whilst various features are described as being essential or necessary, this may only be the case for the proposed 3GPP LTE standard, for example due to other requirements imposed by the standard. These statements should not, therefore, be construed as limiting the present invention in any way.

1. Introduction/Background

At the RAN2/RAN3/SA2 joint meeting in St.Louis, the SAE/LTE architectural principles were agreed and the decision was to move the PDCP layer down to the eNB. At the following RAN2 meeting in Malta it was decided that the ciphering would be performed at the PDCP layer using PDCP Sequence Numbers. Based on this decision user plane handling during handover needs further consideration. This contribution provides the details of the simple user plane data handling based on these decisions taking the handover requirements into account.

2. Handover Requirements

In LTE system it would be desirable to have the following requirements in order to have a well performing and optimised hard handover between eNBs

1. Lossless HHO for the NRT Services in order achieve high TCP throughput performance.
2. Seamless HHO for RT services to minimise the packet loss in order to have good
3. end to end performance of the application.
4. Minimization of duplicate packet transmission over the air interface.
5. Minimal interruption time for the user plane data.
6. In sequence delivery of NAS PDUs should be maintained during HO.
7. No duplication and out of sequence delivery should be visible to ROHC and application.

3. Ciphering and U-plane handling using PDCP SN

Since Ciphering is now decided to be performed at the PDCP layer using PDCP sequence numbers (16 bits), it would probably be desirable to reuse PDCP SN at the RLC sub layer to reduce the RLC Sequence Number overhead (16 bits) by using an OFFSET and LENGTH which indicate the position and length of the RLC segment in the original RLC SDU [1][2].

Following this decision, we should meet the HO requirements that are stated above and should have well performing and optimised handover between eNB. We think that we can effectively utilize the PDCP SN for user plane handling to provide efficient inter-eNB mobility without introducing additional complexity. The buffer can be maintained at the PDCP sub-layer before the ciphering is done as shown in Figure 5.

We believe, with this decision, we can maintain the PDCP SN during HO and use the selective forwarding/retransmission mechanism that was agreed earlier. With Selective forwarding source eNB selectively forward all downlink SDUs that have not been acknowledged by the UE to the target eNB, and discard any remaining downlink RLC PDUs segments. Upon handover, the source eNB forwards uplink PDCP SDUs successfully received in-sequence to the SAE Gateway, forwards uplink PDCP SDUs received out-of-sequence to the target eNB and discards any remaining uplink RLC PDUs. The uplink PDCP SDUs received out-of-sequence needs to be marked as Uplink Packets at the PDCP layer before they are forwarded to the target eNB PDCP layer.

The decision of which SDUs to forward can be based on RLC status reports (for NRT traffic) or HARQ feedback information (for of RT Traffic). As indicated in the simulation results in [3] we need to consider that there could be a maximum of up to 90 SDUs and on an average around 40 SDUs that are received correctly by the UE but not acknowledged at the source eNB. In order to minimise and possibly eliminate the duplicated packet transmission over the air, the exchange of status reports is needed in the source cell when the HO Command is sent to the UE. It is proposed that the RLC status reports exchanged at the time of handover are based on the RLC SDUs using PDCP SNs as status reports based on RLC PDUs may not be much useful and could be larger in size which may delay the Handover. With PDCP SN based Status Report the size of the Status PDU can be reduced to an order of tens of bytes, facilitating fast transmission at the time of handovers.

4. Conclusions

With the Ciphering now being decided to be performed at the PDCP sublayer using PDCP SN, It is proposed that

- Buffers are maintained at the PDCP layer above the Ciphering function to forward/retransmit packets during inter-eNB handovers to achieve lossless handovers
- PDCP SN are maintained at HO
- Reordering is performed at PDCP sublayer based on PDCP SN
- RLC reuses PDCP SN instead of having a separate SN at RLC
- PDCP layer marks the uplink PDCP SDUs received out-of-sequence before source eNB forwards it to the target eNB.
- Selective Forwarding/retransmission of PDCP SDUs with PDCP SN is performed.
- RLC Status Reports based on PDCP SNs are exchanged in the source cell at the time of handover to eliminate duplicated packet transmission over the air.

With these functionality incorporated for user plane handling for inter-eNB handling we believe that we will able to efficiently use the PDCP Sequence Numbers and have a well performing hard handovers for LTE.

References

[1] R2-062754, "PDCP/RLC/MAC PDU structure", Nokia

[2] R2-062800, "Sequence Numbering & Reuse of PDCP SN", InterDigital

[3] R2-063389, Inter-eNB Handover (UP), NTT DoCoMo

Claims

1. A communication method performed by a node of a telecommunication system, the method comprising:

receiving a sequence of PDCP Service Data Units, SDUs, for transmission to another communication node;

appending a sequence number to each PDCP SDU;

storing a copy of the PDCP SDUs with appended sequence number in a PDCP buffer;

ciphering the PDCP SDUs;

passing the ciphered PDCP SDUs with appended sequence numbers to an Outer ARQ entity for segmentation;

segmenting the ciphered PDCP SDUs with appended sequence numbers to generate Outer ARQ segments;

generating and appending a respective Outer ARQ header to each Outer ARQ segment to generate a corresponding Outer ARQ Protocol Data Unit, PDU, which header includes data identifying the position of the Outer ARQ segment within the corresponding PDCP SDU;

sending the generated Outer ARQ PDUs to the other communication node;

receiving acknowledgements for transmitted Outer ARQ PDUs; and

purging each PDCP SDU from the PDCP buffer once acknowledgements have been received for the Outer ARQ PDUs containing the PDCP SDU.

2. A method according to claim 1 performed in a source node of the telecommunication system in which the other communication node is a mobile communication device and further comprising receiving a handover response from a target node and in response stopping transmission of data packets to the mobile communication device and forwarding PDCP SDUs with their appended sequence number stored in said PDCP buffer to the target node.

3. A method according to claim 2, further comprising continuing to receive at said source node data packets from the mobile communication device

after stopping transmission of said data packets to the mobile communications device from said source node.

4. A method according to claim 3, further comprising checking if those data packets received at the source node from the mobile communication device include acknowledgements for any transmitted Outer ARQ PDUs and, if appropriate, removing a PDCP SDU from the PDCP buffer before it is forwarded to the target node.

5. A method according to any of claims 2 to 4, further comprising sending from the target node to the mobile communication device, Outer ARQ PDUs corresponding to the PDCP SDUs received from the source node.

6. A method according to claim 5, comprising sending Outer ARQ PDUs corresponding to the forwarded PDCP SDUs to the mobile node after completion of handover from the source node to the target node.

7. A method according to any of claims 2 to 6, wherein a Radio Resource Control, RRC, entity in the source node receives a handover response from the target node and instructs the Outer ARQ entity to stop the downlink user data transmission.

8. A method according to claim 7, wherein said RRC entity instructs said ARQ entity to send a status report to the ARQ entity of the mobile telecommunication device before instructing the stopping of the downlink user data transmission.

9. A method according to claim 7 or 8, wherein said RRC entity instructs said a PDCP entity to forward downlink PDCP SDUs from said PDCP buffer to said target node after stopping the downlink user data transmission.

10. A method according to any of claims 7 to 9, wherein a Radio Resource Control, RRC, entity in the mobile communication device receives a handover command from the source node and in response instructs the Outer

ARQ entity in the mobile communication device to stop the uplink user data transmission.

11. A method according to claim 10, wherein said RRC entity of said mobile communication device instructs said ARQ entity of the mobile communication device to send a status report to the ARQ entity of the source node before instructing the stopping of the uplink user data transmission.

12. A method according to claim 8 or 11, wherein said status report identifies the sequence number of the last in-sequence PDCP SDU received and of any received out-of-sequence PDCP SDUs.

13. A method according to any preceding claim, comprising receiving uplink Outer ARQ PDUs from the other communication node, removing an Outer ARQ header from each received Outer ARQ PDU and concatenating received ARQ PDUs to form PDCP SDUs with sequence number.

14. A method according to claim 13, comprising buffering out-of-sequence PDCP SDUs received from the other communication node.

15. A method according to claim 14 performed in a source node of a telecommunication system in which the other node is a mobile communication device and further comprising receiving a handover response from a target node and in response marking out-of-sequence uplink PDCP SDUs stored in said PDCP buffer as uplink data and forwarding the marked out-of-sequence uplink PDCP SDUs to the target node.

16. A method according to claim 15, wherein the target node differentiates between uplink and downlink PDCP SDUs and transmits downlink PDCP SDUs to the mobile communication device and passes the uplink PDCP SDUs to the telecommunication network once it has received the missing PDCP SDUs from the mobile telecommunication device.

17. A method of facilitating handover of a mobile communication device from a source node to a target node, the method being performed in the source node and comprising, in response to receiving a handover response from the target node:

stopping the transmission of downlink Outer ARQ PDUs from the source node to the mobile communication device;

transmitting a handover command to said mobile communication device after stopping the transmission of said downlink user data;

receiving a status packet from the mobile communication device, which status packet identifies the last in-sequence PDCP SDU received from the source node and any out-of-sequence PDCP SDUs received from the source node; and

forwarding PDCP SDUs to the target node in dependence upon the identified PDCP SDUs received by the mobile communication device.

18. A method of facilitating handover of a mobile communication device from a source node to a target node, the method being performed in the target node and comprising, in response to transmitting a handover response to the source node:

receiving forwarded downlink PDCP SDUs from the source node;

receiving forwarded uplink out-of-sequence PDCP SDUs from the source node;

transmitting Outer ARQ PDUs corresponding to the received downlink PDCP SDUs to the mobile communication device;

receiving Outer ARQ PDUs from the mobile communication device and forming from them corresponding PDCP SDUs with sequence numbers; and

reordering the received PDCP SDUs and the forwarded PDCP SDUs based on their sequence numbers and forwarding them in sequence to a telecommunication network.

19. A method performed by a mobile communication device at handover from a source node to a target node, the method comprising:

receiving a status packet from the source node identifying the last in-sequence uplink PDCP SDUs received by the source node and any out-of-sequence PDCP SDUs received by the source node;

receiving a handover command from the source node;

transmitting a status packet to the source node identifying the last in-sequence downlink PDCP SDU received from the source node and any out-of-sequence PDCP SDUs received from the source node;

stopping transmission of data packets to the source node;

establishing a communication link with the target node;

determining PDCP SDUs to be transmitted/retransmitted to the target node based on the status packet received from the source node; and

transmitting/retransmitting the determined PDCP SDUs to the target node.

20. A communication node adapted to perform the method of any preceding claim.

21. A computer implementable instructions product comprising computer implementable instructions for causing a computer device to carry out the method of any of claims 1 to 19.

22. A communication node comprising:

means for receiving a sequence of PDCP Service Data Units, SDUs, for transmission to another communication node;

means for appending a sequence number to each PDCP SDU;

means for storing a copy of the PDCP SDUs with appended sequence number in a PDCP buffer;

means for ciphering the PDCP SDUs;

means for passing the ciphered PDCP SDUs with appended sequence numbers to an Outer ARQ entity for segmentation;

means for segmenting the ciphered PDCP SDUs with appended sequence numbers to generate Outer ARQ segments;

means for generating and appending a respective Outer ARQ header to each Outer ARQ segment to generate a corresponding Outer ARQ Protocol

Data Unit, PDU, which header includes data identifying the position of the Outer ARQ segment within the corresponding PDCP SDU;

means for sending the generated Outer ARQ PDUs to the other communication node;

means for receiving acknowledgements for transmitted Outer ARQ PDUs; and

means for purging each PDCP SDU from the PDCP buffer once acknowledgements have been received for the Outer ARQ PDUs containing the PDCP SDU.

UK Intellectual Property Office
For Creativity and Innovation

Application No:	GB0708455.1	**Examiner:**	Owen Wheeler
Claims searched:	1,22	**Date of search:**	20 August 2007

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1,22 at least	EP 1343267 A2 [ASUSTEK] See paragraph 36.
A	-	EP 1686736 A1 [STACK] See Fig. 5 and paragraphs 5,61,77,78.
A	-	US 2006/098574 A1 [YI] See paragraph 45.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention
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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

H04L

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI

International Classification:

Subclass	Subgroup	Valid From
H04L	0001/18	01/01/2006
H04B	0007/26	01/01/2006