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(71) Applicant: **TELEFONAKTIEBOLAGET L M ERICSSON (PUBL)** [SE/SE]; S-164 83 Stockholm (SE).

(72) Inventor: **SUNELL, Kai-Erik**; Synålsvägen 7, S-168 73 Bromma (SE).

(74) Agent: **AYOUB, Nabil**; Ericsson AB, Patent Unit Kista RAN2, 164 80 Stockholm (SE).

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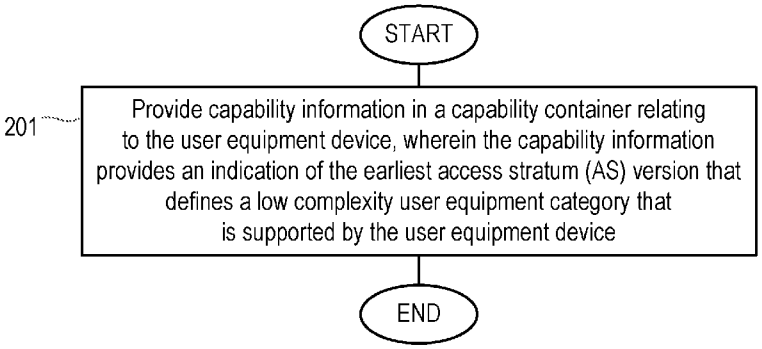

Figure 2

(57) Abstract: A method in a user equipment comprises the step of providing capability information in a capability container relating to the user equipment, wherein the capability information provides an indication of the earliest access stratum (AS) version that defines a low complexity user equipment category that is supported by the user equipment (step 201).

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Method and Apparatus for Handover Procedures in a Communication Network

Technical Field

The present invention relates to a method and apparatus for handover procedures in a communication network, for example handover procedures involving low complexity category user equipment.

Background

Communication devices such as terminals are also known as, for example, User Equipment (UE), mobile terminals, wireless terminals and/or mobile stations. Terminals are enabled to communicate wirelessly in a cellular communications network or wireless communication system, sometimes also referred to as a cellular radio system or cellular network. The communication may be performed e.g. between two terminals, between a terminal and a regular telephone and/or between a terminal and a server via a Radio Access Network (RAN) and possibly one or more core networks, comprised within the cellular communications network.

Examples of wireless communication systems are Long Term Evolution (LTE), Universal Mobile Telecommunications System (UMTS) and Global System for Mobile communications (GSM).

Terminals may further be referred to as mobile telephones, cellular telephones, laptops, or surf plates with wireless capability, just to mention some further examples. The terminals in the present context may be, for example, portable, pocket-storable, hand-held, computer-comprised, or vehicle-mounted mobile devices, machine to machine devices, enabled to communicate voice and/or data, via the RAN, with another entity, such as another terminal or a server.

The cellular communications network covers a geographical area which is divided into cell areas, wherein each cell area is served by an access node such as a base station, e.g. a Radio Base Station (RBS), which sometimes may

be referred to as e.g. “eNB”, “eNodeB”, “NodeB”, “B node”, or BTS (Base Transceiver Station), depending on the technology and terminology used. The base stations may be of different classes, for example such as macro eNodeB, home eNodeB or pico base stations, based on transmission power and thereby also cell size. A cell is the geographical area where radio coverage is provided by the base station at a base station site. One base station, situated on the base station site, may serve one or several cells. Further, each base station may support one or several communication technologies. The base stations communicate over the air interface operating on radio frequencies with the terminals within range of the base stations. In the context of this disclosure, the expression Downlink (DL) is used for the transmission path from the base station to the mobile station. The expression Uplink (UL) is used for the transmission path in the opposite direction i.e. from the mobile station to the base station.

In 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE), base stations, which may be referred to as eNodeBs or eNBs, may be directly connected to one or more core networks.

Radio access standards relating to 3GPP LTE have been written in order to support high bitrates and low latency both for uplink and downlink traffic. Data transmission in LTE is controlled by the radio base station.

One function of 3GPP cellular radio technologies is the control of user mobility by using the Radio Resource Control (RRC) and X2AP protocols. The network controls the handover of UEs in a RRC Connected mode from one cell to another, whereas a UE in Idle mode performs cell selection and reselection itself. Embodiments herein are illustrated with examples from the Evolved Universal Terrestrial Radio Access (EUTRA), also known as the LTE system.

When a UE is handed over from a source cell to a target cell, handover preparation is needed. Upon handover preparation the target radio base station or eNB is provided with the current UE RRC configuration, for example which

may be comprised in a handover preparation information message (such as the *HandoverPreperationInformation* message, for example as described in 3GPP Technical Specification TS 36.331, version 12.1.0). This message is used to transfer the E-UTRA RRC information used by the target eNB during handover preparation, including UE capability information. The target eNB decides the RRC configuration after the handover and therefore a RRC configuration message is transparently sent to the UE via the source eNB as an octet string comprised in the handover command. Normally full configuration is required if the target eNB has a different Access Stratum (AS) version than the source eNB.

If the RRC configuration in the handover preparation message is incomplete or the source cell has configured the UE with a RRC protocol version that is not comprehended by the target eNB, the target eNB typically performs a full configuration (if possible), i.e. performs a reconfiguration from scratch. Otherwise the target eNB may modify or maintain the current RRC configuration.

3GPP has recently agreed within the scope of low-cost Machine Type Communication (MTC) work item to introduce a new UE category termed as a "low complexity category" (which may also be referred to as category 0, or category 11). The category 0 is included in the 3GPP Technical Specification TS 36.331 RRC, Rel-12, version 12.5.0. A problem arises, since this new category is less capable than legacy UE categories, for example, legacy category 1. Furthermore, the legacy categories (including categories 1, 2, 3, 4 and 5 that were first introduced with Release 8 of the RRC protocol), such as category 1, are mandatory to signal even though the low complexity category UE does not have any such category, and thus full configuration will always be required from the legacy eNB because it has a different AS version than the source eNB. In other words, since a legacy UE-Category field is mandatory required to be present in the UE-EUTRA-Capability container, omitting such a mandatory field results in a decoding error, and therefore to avoid this all UEs shall indicate one category in the mandatory field even if they do not support

any such category.

Accordingly, upon handover preparation, a legacy target eNB that does not comprehend the new low complexity category may erroneously assume that the UE may be successfully configured with the indicated legacy category, for example a legacy category such as category 1. Consequently, the handover fails and the UE experiences a radio link failure. Subsequently, the UE tries to trigger RRC Connection Re-establishment which also fails. Finally the UE transitions to Idle mode where it searches for suitable cells.

This has the disadvantage of causing unnecessary signaling due to the failed handovers and the unsuccessful RRC connection re-establishment requests, which results in the inefficient use of bandwidth.

Summary

It is an aim of the present invention to provide a method and apparatus which obviate or reduce at least one or more of the disadvantages mentioned above.

According to a first aspect of the present invention there is provided a method in a user equipment. The method comprises the step of providing capability information in a capability container relating to the user equipment, wherein the capability information provides an indication of the earliest access stratum (AS) version that defines a low complexity user equipment category that is supported by the user equipment.

According to another aspect of the present invention, there is provided a method in a user equipment. The method comprises the step of providing a protocol field in a UE-EUTRA-Container to indicate that the UE does not support legacy categories 1, 2, 3, 4 or 5.

According to another aspect of the present invention, there is provided a method in a user equipment. The method comprises the step of providing a protocol field in a UE-EUTRA-Container to indicate that the UE only supports a

low complexity category relating to Release 12 and above.

According to another aspect of the present invention there is provided a method in a target base station during a handover preparation procedure of a user equipment (UE) from a source base station to the target base station. The method comprises the steps of receiving a capability container relating to the user equipment, and interpreting capability information in the capability container to determine the earliest access stratum (AS) version that defines a low complexity user equipment category that is supported by the user equipment. The result of the interpretation is used to determine whether the handover operation should be continued with the user equipment.

According to another aspect of the present invention, there is provided a user equipment comprising a processor module and a protocol field module. The protocol field module is adapted to provide capability information in a capability container relating to the user equipment, wherein the capability information provides an indication of the earliest access stratum (AS) version that defines a low complexity user equipment category that is supported by the user equipment.

According to another aspect of the present invention, there is provided a network node of a communications network, for example a target base station node, for example a target eNB. The network node comprises a processing module, an interpreting module and a processor module. The receiving module is adapted to receive a capability container relating to a user equipment. The interpreting module is adapted to interpret capability information in the capability container to determine the earliest access stratum (AS) version that defines a low complexity user equipment category that is supported by the user equipment. The processor module is adapted to use the result of the interpretation module to determine whether a handover operation should be performed with the user equipment.

Brief description of the drawings

For a better understanding of examples of the present invention, and to show more clearly how the examples may be carried into effect, reference will now be made, by way of example only, to the following drawings in which:

Figure 1 shows an example of a communication network in which embodiments of the invention may be used;

Figure 2 shows a method according to an embodiment of the invention;

Figure 3 shows a method according to another embodiment of the invention;

Figure 4 shows a method according to another embodiment of the invention;

Figure 5 shows a method according to another embodiment of the invention;

Figure 6 shows a method according to another embodiment of the invention;

Figure 7 shows a user equipment according to an embodiment of the invention; and

Figure 8 shows a network node according to an embodiment of the invention.

Detailed description

The embodiments of the invention, as described herein, introduce an additional or new protocol field in a UE capability container, or reuse a legacy information element, where the UE indicates the earliest supported Access Stratum (AS) release or version. A network node, such as a target eNB can obtain the indicator from the UE capability container, which may be included in a handover preparation information message provided, for example, by a source eNB. If the target eNB does not support the indicated earliest supported AS release of the UE, the handover preparation can be rejected by the target eNB. In that way, the source eNB can try to handover the UE to another eNB or to another frequency. By “new” or “additional” protocol field it

is meant that the protocol field is provided for the purpose of assisting handover for low complexity category UE devices.

The embodiments of the invention described herein have the advantage that unnecessary signaling caused by failed handovers and unsuccessful RRC connection re-establishments are avoided. Consequently, network resources are used in a more efficient manner and UE battery lifetime is prolonged.

Terminologies

The following common terminologies are used in the embodiments and are elaborated below:

Network node: In some embodiments a term "network node" is used and it may correspond to any type of radio network node or any network node, which communicates with at least a radio network node.

User equipment: In some embodiments the non-limiting term user equipment (UE) is used and it refers to any type of wireless device communicating with a radio network node in a cellular or mobile communication system. Examples of UEs are target device, device to device UE, MTC UE or UE capable of machine to machine communication, PDA, iPAD, Tablet, mobile terminals, smart phone, laptop embedded equipped (LEE), laptop mounted equipment (LME), USB dongles etc.

It is noted that although terminology from 3GPP LTE/SAE has been used in this disclosure to exemplify the embodiments herein, this should not be seen as limiting the scope of the embodiments herein to only the aforementioned system. Other wireless systems may also benefit from exploiting the ideas covered within this disclosure.

It is also noted that terminology such as a first network node and a second network node should be considered to be non-limiting and does in particular not imply a certain hierarchical relation between the two.

In this section, the embodiments herein will be illustrated in more detail by a number of exemplary embodiments. It should be noted that these embodiments are not mutually exclusive. Components from one embodiment may be tacitly assumed to be present in another embodiment and it will be obvious to a person skilled in the art how those components may be used in the other exemplary embodiments.

Prior to describing the embodiments of the present invention, reference will first be made to Figure 1, which depicts parts of one or more wireless communications networks 100 in which the embodiments herein may be implemented. The one or more wireless communications networks 100 may for example be LTE, UMTS, GSM, and 3GPP wireless communications networks, or any cellular wireless communications network or system capable of handling UEs of more than one category or of different capabilities.

The wireless communications network 100 comprises a plurality of base stations and/or other network nodes. More specifically, the wireless communications network 100 comprises a first network node 111. The first network node 111 is also referred to herein as a source network node. The wireless communications network 100 further comprises a second network node 112. The second network node 112 is also referred to herein as a candidate or target network node. The first and second network nodes 111, 112 may be a base station, such as an eNB. The base station may also be referred to as a NodeB, an evolved Node B (eNB, eNode B), a base transceiver station (BTS), Access Point Base Station, base station router, or any other network unit capable of communicating with a user equipment within a cell served by the base station depending e.g. on the radio access technology and terminology used.

In some embodiments the first network node 111 and the second network node 112 belong to two different wireless communications networks. For example, the first network node 111 may belong to an UMTS network and the second

network node 112 may belong to an LTE network. The first network node 111 may then be a Radio Network Controller (RNC) in the UMTS network. The first network node 111 may serve a first cell 121, also referred to as a source cell, the second network node 112 may serve a second cell 122, also referred to as a candidate cell or target cell.

A cell is a geographical area where radio coverage is provided by network node equipment such as WiFi AP equipment, base station equipment at a base station site or at remote locations in Remote Radio Units (RRU). The first network node is an example of such network node equipment. The cell definition may also incorporate frequency bands and radio access technology used for transmissions, which means that two different cells may cover the same geographical area but using different frequency bands. Each cell is identified by an identity within the local radio area, which is broadcast in the cell. Another identity for identifying cells uniquely in the whole of a wireless communication network is also broadcasted in the cells. Network nodes, such as base stations and WiFi AP, communicate over the air or radio interface operating on radio frequencies with the user equipments within range of the network nodes. The user equipment transmit data over the radio interface to network nodes, such as base stations and WiFi AP, in Uplink (UL) transmissions, and network nodes, such as WiFi AP and base stations, transmit data over an air or radio interface to the user equipment in Downlink (DL) transmissions.

The first network node 111 communicates with user equipments in the first cell 121, such as a user equipment 140 of the first category, also referred to as an UE or a wireless device, which is to be handed over to a cell different from the first cell 121. The handover may, for example, be due to mobility of the user equipment 140. The user equipment 140 is of the first category, i.e. a low complexity category (or category 0), for example an MTC user equipment.

The user equipment 140 may e.g. be a mobile terminal or a wireless terminal, a mobile phone, a computer such as a laptop, a Personal Digital Assistants

(PDAs) or a tablet computer, sometimes referred to as a surf plate, with wireless capability, or any other radio network units capable of communicating over a radio link in a wireless communications network. It is noted that the term user equipment used in this document also covers other wireless devices such as Machine to machine (M2M) devices, even though they do not have any user.

More specifically the following are embodiments related to the user equipment, target network node and source network node, for example relating to handover procedures that may involve user equipment having a low complexity category.

According to one embodiment, there is defined an enhanced or new protocol UE capability container as defined in TS 36.331 Radio Resource Control (RRC) protocol, version 12.1.0, sub-clause 6.3.6. A field indicates the earliest supported AS release or version.

An example of one possible way of specifying the field, according to an embodiment of the invention, is to define an enumerated list of AS release values and make use of the legacy AS indication information element which is then defined as follows (and with the further details given later in the application relating to protocol field "*earliestSupported-AS")* :

```
AccessStratumRelease ::=            ENUMERATED {
                                        rel8, rel9, rel10, rel11, spare4, spare3,
                                        spare2, spare1, ...}
```

Alternatively, according to another embodiment a new, i.e. additional information element can be defined with less code points than in a legacy information element because the low complexity categories are introduced so late as in Rel-12.

The additional information element can be composed of only a code point that indicates whether the earliest supported AS version is earlier than Rel-12, i.e. where the first low complexity category is introduced. According to one

example the additional protocol field is defined in terms of abstract syntax notation in the following manner:

```
legacyCategory          ENUMERATED {notsupported}          OPTIONAL,
```

This type of indication means that the UE indicates that its earliest supported AS version is Rel-12 and therefore the UE does not support any of the legacy categories, i.e. does not support categories 1, 2, 3, 4 or 5 that were introduced with Rel-8. As such, by specifying that the earliest supported AS version is Rel-12, this implies that the UE does not support legacy UE categories. An example of the semantics of the protocol field is described below:

legacyCategory

The presence indicates that the UE does not support the indicated Rel-8 category 1, 2, 3, 4 or 5. This can be used by a target eNB during handover preparation to decide if a RRC configuration can be prepared with the indicated Rel-8 category. Absence of the field means that the UE supports the indicated Rel-8 category.

In an embodiment that uses a legacy information element to convey the required capability information (instead of providing an additional or new protocol field as described above) the introduction of the protocol field based on the reused *AccessStratumRelease* information element is exemplified below where the field is included in a noncritical extension defined in terms of abstract syntax
notation.

```
UE-EUTRA-Capability ::=          SEQUENCE {
    accessStratumRelease                AccessStratumRelease,
    ue-Category                         INTEGER (1..5),
    pdcp-Parameters                     PDCP-Parameters,
    phyLayerParameters                  PhyLayerParameters,
    rf-Parameters                       RF-Parameters,
    measParameters                      MeasParameters,
    featureGroupIndicators              BIT STRING (SIZE (32))              OPTIONAL,
    interRAT-Parameters               SEQUENCE {
```

```
        utraFDD                              IRAT-ParametersUTRA-FDD              OPTIONAL,
        utraTDD128                           IRAT-ParametersUTRA-TDD128               OPTIONAL,
        utraTDD384                           IRAT-ParametersUTRA-TDD384               OPTIONAL,
        utraTDD768                           IRAT-ParametersUTRA-TDD768               OPTIONAL,
        geran                                IRAT-ParametersGERAN                     OPTIONAL,
        cdma2000-HRPD                        IRAT-ParametersCDMA2000-HRPD             OPTIONAL,
        cdma2000-1xRTT                       IRAT-ParametersCDMA2000-1XRTT            OPTIONAL
    },
    nonCriticalExtension                UE-EUTRA-Capability-v920-IEs        OPTIONAL
}

-- Regular non critical extensions
UE-EUTRA-Capability-v920-IEs ::=        SEQUENCE {
    phyLayerParameters-v920             PhyLayerParameters-v920,
    interRAT-ParametersGERAN-v920           IRAT-ParametersGERAN-v920,
    interRAT-ParametersUTRA-v920            IRAT-ParametersUTRA-v920            OPTIONAL,
    interRAT-ParametersCDMA2000-v920        IRAT-ParametersCDMA2000-1XRTT-v920  OPTIONAL,
    deviceType-r9                           ENUMERATED {noBenFromBatConsumpOpt} OPTIONAL,
    csg-ProximityIndicationParameters-r9    CSG-ProximityIndicationParameters-r9,
    neighCellSI-AcquisitionParameters-r9    NeighCellSI-AcquisitionParameters-r9,
    son-Parameters-r9                       SON-Parameters-r9,
    nonCriticalExtension                    UE-EUTRA-Capability-v940-IEs        OPTIONAL
}

UE-EUTRA-Capability-v940-IEs ::=    SEQUENCE {
    lateNonCriticalExtension            OCTET STRING (CONTAINING UE-EUTRA-Capability-v9a0-IEs)
                                                                                OPTIONAL,
    nonCriticalExtension                UE-EUTRA-Capability-v1020-IEs       OPTIONAL
}

UE-EUTRA-Capability-v1020-IEs ::=   SEQUENCE {
    ue-Category-v1020                   INTEGER (6..8)                          OPTIONAL,
    phyLayerParameters-v1020            PhyLayerParameters-v1020                OPTIONAL,
    rf-Parameters-v1020                 RF-Parameters-v1020                     OPTIONAL,
    measParameters-v1020                MeasParameters-v1020                    OPTIONAL,
    featureGroupIndRel10-r10            BIT STRING (SIZE (32))                  OPTIONAL,
    interRAT-ParametersCDMA2000-v1020   IRAT-ParametersCDMA2000-1XRTT-v1020     OPTIONAL,
    ue-BasedNetwPerfMeasParameters-r10  UE-BasedNetwPerfMeasParameters-r10      OPTIONAL,
    interRAT-ParametersUTRA-TDD-v1020   IRAT-ParametersUTRA-TDD-v1020           OPTIONAL,
    nonCriticalExtension                UE-EUTRA-Capability-v1060-IEs           OPTIONAL
}

UE-EUTRA-Capability-v1060-IEs ::=   SEQUENCE {
    fdd-Add-UE-EUTRA-Capabilities-v1060 UE-EUTRA-CapabilityAddXDD-Mode-v1060    OPTIONAL,
    tdd-Add-UE-EUTRA-Capabilities-v1060 UE-EUTRA-CapabilityAddXDD-Mode-v1060    OPTIONAL,
    rf-Parameters-v1060                 RF-Parameters-v1060                     OPTIONAL,
    nonCriticalExtension                UE-EUTRA-Capability-v1090-IEs           OPTIONAL
}

UE-EUTRA-Capability-v1090-IEs ::=   SEQUENCE {
    rf-Parameters-v1090                 RF-Parameters-v1090                     OPTIONAL,
    nonCriticalExtension                UE-EUTRA-Capability-v1130-IEs           OPTIONAL
}

UE-EUTRA-Capability-v1130-IEs ::=   SEQUENCE {
    pdcp-Parameters-v1130               PDCP-Parameters-v1130,
    phyLayerParameters-v1130            PhyLayerParameters-v1130                OPTIONAL,
    rf-Parameters-v1130                 RF-Parameters-v1130,
    measParameters-v1130                MeasParameters-v1130,
    interRAT-ParametersCDMA2000-v1130   IRAT-ParametersCDMA2000-v1130,
    otherParameters-r11                 Other-Parameters-r11,
    fdd-Add-UE-EUTRA-Capabilities-v1130 UE-EUTRA-CapabilityAddXDD-Mode-v1130    OPTIONAL,
    tdd-Add-UE-EUTRA-Capabilities-v1130 UE-EUTRA-CapabilityAddXDD-Mode-v1130    OPTIONAL,
    nonCriticalExtension                UE-EUTRA-Capability-v1170-IEs           OPTIONAL
}

UE-EUTRA-Capability-v1170-IEs ::=   SEQUENCE {
    phyLayerParameters-v1170            PhyLayerParameters-v1170                OPTIONAL,
    ue-Category-v1170                   INTEGER (9..10)                         OPTIONAL,
    nonCriticalExtension                UE-EUTRA-Capability-v12xy-IEs           OPTIONAL
}

UE-EUTRA-Capability-v12xy-IEs ::= SEQUENCE {
    earliestSupported-AS                AccessStratumRelease                    OPTIONAL,
    nonCriticalExtension                SEQUENCE {}                             OPTIONAL
```

}

The new information according to embodiments of the invention is shown in bold at the bottom of the table above.

The enumeration may contain spare values for future releases, and they can be used in the same manner as with the normal AS release indicator. The protocol field description includes semantics of the field and explanation of the possible use at the network side, for example as described below:

earliestSupported-AS

The protocol field "*earliestSupported-AS*" indicates, e.g. to a target eNB, the earliest Access Stratum release that defines a low complexity category that is supported by the UE. It is noted that the expression "*earliestSupported-AS*" is merely an example of the notation that may be used, and that other expressions may be used to denote the same field. This can be used by other network nodes, for example by a target eNB, to decide if handover is possible for the UE. If this field is not present, the target (e.g. eNB) assumes that the UE can support all categories from the Rel-8 version of the RRC protocol. In this manner, this is all of the information that the target, such as an eNB needs, and a target eNB may also infer other information, for example that the UE supports a low complexity category that is not supported by the target eNB, even though the target eNB does not comprehend the exact value of the category because it does not implement a future Release. This is sufficient for a target eNB to make a decision about whether the UE should be handed over or not.

It is noted that the reference to the expression "*AccessStratumRelease*" in the syntax above is merely an example of the notation that may be used, and that other expressions may be used to denote the same field.

The embodiments of the invention make use of methods for populating the additional protocol field in the UE side of the radio interface and interpreting the populated value at the network side during handover preparation. An example of the method at the UE side of the radio interface is as follows:

1. If the UE supports low complexity categories and does not support any of the legacy categories, include the protocol field in the message. Otherwise go to step 3.
2. Set the protocol field to a value that indicates the earliest AS version that defines a low complexity category that is supported by the UE.
3. Procedure ends.

Figure 2 shows the steps performed in a user equipment according to an embodiment of the invention. The method comprises the step of providing capability information in a capability container relating to the user equipment, wherein the capability information provides an indication of the earliest access stratum (AS) version that defines a low complexity user equipment category that is supported by the user equipment, step 201.

The capability information may comprise a protocol field in the capability container relating to the user equipment.

According to one embodiment the protocol field comprises an additional protocol field. For example, the additional protocol field can provide an indication as to whether the earliest supported AS version is earlier than Release 12.

In such an embodiment the presence of the additional protocol field in the capability container of the UE provides an indication to other network nodes that the UE is not capable of supporting other UE categories of earlier AS versions (for example cannot support categories 1, 2, 3, 4 or 5 of versions Rel-8, Rel-9, Rel-10 or Rel-11).

In other words, in such an embodiment the absence of the additional protocol field in the capability container of the UE provides an indication to other network nodes that the UE is capable of supporting other UE categories of earlier AS

versions, including categories 1 to 5 of Rel-8 and above.

The additional protocol field may comprise a one bit indicator, and may reference, for example, a *LegacyCategory* information element.

According to another embodiment the protocol field comprises a legacy information element that is reused to provide the capability information. For example, the protocol field may comprise an *AccessStratumRelease* information element.

In such an embodiment the A*ccessStratumRelease* information element may comprise an enumerated list of the AS release values supported by the UE.

The A*ccessStratumRelease* information element may further comprise one or more spare values for use with future AS release values. The protocol field may be included in a noncritical extension defined in terms of abstract syntax notation.

Figure 3 shows the method performed in a user equipment according to another embodiment of the present invention.

In step 301 it is determined if the UE supports a low complexity category. In step 303 it is determined if the UE does not support any legacy categories. If these criteria are met, the protocol field is set to a value that indicates the earliest AS version that defines a low complexity category that is supported by the UE, step 305.

The capability information (for example provided as an additional protocol field or a reused information element) can be used by a target base station during a handover preparation procedure to determine if handover is possible for the UE with that target base station.

Upon handover preparation the source eNB normally provides the UE-EUTRA

capability information to the target eNB. The target eNB requires a method for interpretation of the capability information, the results of which can be used to assist with a decision regarding whether to accept or reject the handover preparation. According to an embodiment of the invention, the target eNB logic for interpretation of the value can be described, for example, with the following method:

1. If the *earliestSupported-AS* release is present and set to an unknown value or the value is present but unspecified in the eNB's supported RRC protocol version, consider that the UE does not support the indicated Rel-8 category and go to step 5.
2. If the *earliestSupported-AS* release is present and set to a value that is higher than the target eNB is able to handle, consider that the UE does not support the indicated Rel-8 categories and go to step 5.
3. If the *earliestSupported-AS* release is present and set to a value that is specified in the eNB's supported RRC protocol version and the AS release indication is comprehended and supported, consider that the UE does not support the indicated Rel-8 categories and go to step 5.
4. If the earliestSupported-AS release is absent, consider that the UE supports the indicated Rel-8 category.
5. Interpretation procedure ends.

After the interpretation, the target eNB can decide whether to reject or accept the handover preparation. This type of decision can be based on many aspects where the outcome of the above-described interpretation method is taken into account.

Figure 4 shows a method performed in a target base station according to an embodiment of the present invention, during a handover preparation procedure of a user equipment (UE) from a source base station to the target base station. The method comprises the step of receiving a capability container relating to the user equipment, step 401. In step 403 capability information in the capability container is interpreted to determine the earliest access stratum (AS) version

that defines a low complexity user equipment category that is supported by the user equipment. The result of the interpretation is used to determine whether the handover operation should be continued with the user equipment, step 405.

The interpretation step may comprise determining if an additional protocol field is present or absent, wherein the additional protocol field provides an indication as to whether the earliest supported AS version is earlier than Release 12.

In such an embodiment, determining the presence of the additional protocol field in the capability information relating to the UE provides an indication that the UE is not capable of supporting other UE categories of earlier AS versions. As a consequence, the target base station may take action to halt a handover operation with that UE. For example, upon determining that the additional protocol field is present, the method may further comprises the step of discontinuing a handover procedure with the UE.

In an alternative embodiment, determining the absence of the additional protocol field in the capability information relating to the UE provides an indication that the UE is capable of supporting other UE categories of earlier AS versions, including categories 1 to 5 of Rel-8 and above. Following a determination that the additional protocol field is absent, the method may further comprise the step of continuing a handover procedure with the UE.

The additional protocol field may comprise or may reference, for example, a *LegacyCategory* information element. This may comprise a one bit flag.

The interpretation step performed in the target base station may comprise the step of determining from a reused information element an indication of the earliest access stratum (AS) version that defines a low complexity user equipment category that is supported by the UE.

The interpretation step performed in the target base station may comprise the

step of determining if an earliestSupported-AS release protocol field is present and set to an unknown value, or if the value is present but unspecified in an RRC protocol version supported by the target base station, and if so, considering that the UE does not support an AS Rel-8 category.

The interpretation step performed in the target base station may comprise the step of determining if an "earliestSupported-AS release protocol field is present and set to a value that is higher than the target base station is able to handle, and if so, considering that the UE does not support an AS Rel-8 category.

The interpretation step performed in the target base station may comprise the step of determining if an earliestSupported-AS release is present and set to a value that is specified in an RRC protocol version supported by the target base station, and if the indicated UE category is comprehended and supported, and if so, considering that the UE does not support an AS Rel-8 category.

The interpretation step performed in the target base station may comprise the step of determining if an earliestSupported-AS release protocol field is absent, and if so, considering that the UE supports an AS Rel-8 category.

From the above it can be seen that in an embodiment where the method is performed in the target base station, the absence of a particular protocol field may indicate that the UE can support all categories from a predetermined version of the RRC protocol and above, for example wherein the predetermined version is version 8 of an RRC protocol and above.

Figure 5 shows a method in a user equipment, according to another embodiment of the invention. The method comprises the step of providing a protocol field in a UE-EUTRA-Container to indicate that the UE does not support legacy categories 1, 2, 3, 4 or 5, step 501.

Figure 6 shows a method in a user equipment, according to another embodiment of the invention. The method comprises the step of providing a protocol field in a UE-EUTRA-Container to indicate that the UE only supports a low complexity category relating to Release 12 and above, step 601.

Figure 7 shows a user equipment 700 according to an embodiment of the invention. The user equipment 700 comprises a processor module 701 and a protocol field module 703. The protocol field module 703 is adapted to provide capability information in a capability container relating to the user equipment, wherein the capability information provides an indication of the earliest access stratum (AS) version that defines a low complexity user equipment category that is supported by the user equipment.

In the user equipment 700 of Figure 7, the processor module 701 may be adapted to perform the method steps described above, relating to the user equipment. The user equipment may comprise a memory 705.

Figure 8 shows a network node 800 of a communications network according to another embodiment of the invention, for example a target base station during a handover procedure. The network node 800 comprises a processing module 801, a receiving module 803 and an interpreting module 805. The receiving module 801 is adapted to receive a capability container relating to a user equipment. The interpreting module 805 is adapted to interpret capability information in the capability container to determine the earliest access stratum (AS) version that defines a low complexity user equipment category that is supported by the user equipment. The processor module 801 is adapted to use the result of the interpretation module to determine whether a handover operation should be performed with the user equipment.

In the network node 800 of Figure 8, the processor module 801 may be adapted to perform the method steps as described above in relation to the target base station, for example target eNB.

From the above it can be seen that the embodiments of the invention introduce an additional protocol field (or reuse a legacy information element) in UE capability signaling to indicate the earliest Access Stratum version that defines a low complexity UE category that is supported by the UE. The embodiments of the invention define a method for setting the field value and another method in the target eNB to interpret the value. The outcome of the interpretation determines whether the UE supports legacy categories or not. This interpretation can be used as part of the decision regarding whether or not a handover procedure should be carried out between that UE and that target eNB.

For example, the embodiments of the invention provide a solution to a problem where a target and source eNBs may have different access stratum releases. If the target eNB is of an earlier version that the UE and the source eNB, the target eNB does not comprehend a category information field because it cannot decode future extensions. So, the information for the handover decision is in future extensions that are not comprehended by the target eNB, and therefore UE categories cannot be reliably used for the decision whether to perform a handover or not. Embodiments described herein have the advantage of using, for example, the *AccessStratumRelease* information element, which is forward compatible. The *AccessStratumRelease*, as described above, is a list that was defined in Rel-8, and basically contains code points for future releases (even though they are named as spare values they are still comprehended by all nodes). This means that the indication of *earliestSupported-AS* can indicate, e.g. to a target eNB that is based on a Rel-12 version, that the UE is of e.g. Rel-15, and that the UE has a low complexity category even though the target eNB that is based on Rel-12 is not capable of reading the exact category indication extension and the category number. The target eNB can, however, comprehend the acess stratum version indication, and accordingly it can, for example, reject a handover preparation if it does not know anything about the Rel-15 low complexity categories. As such, a part of the information that is in future extensions (which by definition cannot be comprehended by a legacy target

eNB because it cannot decode future extensions) is effectively smuggled to the target eNB with the access stratum release indication, e.g. with the indication of *earliestSupported-AS* version.

Thus, a benefit of the embodiments described herein is that the ambiguities with category handling are avoided for low complexity UEs by using a protocol field, for example a simple one-bit indicator that overrides the mandatory present legacy category field, or a reused protocol field to identify a list of supported AS versions.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. The word “comprising” does not exclude the presence of elements or steps other than those listed in a claim, “a” or “an” does not exclude a plurality, and a single processor or other unit may fulfil the functions of several units recited in the claims. Any reference signs in the claims shall not be construed so as to limit their scope.

CLAIMS

1. A method in a user equipment, the method comprising the step of providing capability information in a capability container relating to the user equipment, wherein the capability information provides an indication of the earliest access stratum, AS, version that defines a low complexity user equipment category that is supported by the user equipment (step 201).

2. A method as claimed in claim 1, wherein the capability information comprises a protocol field in the capability container relating to the user equipment.

3. A method as claimed in claim 2, wherein the protocol field comprises an additional protocol field.

4. A method as claimed in claim 3, wherein the additional protocol field provides an indication as to whether the earliest supported AS version is earlier than Release 12.

5. A method as claimed in claim 4, wherein presence of the additional protocol field in the capability container of the UE provides an indication to other network nodes that the UE is not capable of supporting other UE categories of earlier AS versions.

6. A method as claimed in claim 4, wherein absence of the additional protocol field in the capability container of the UE provides an indication to other network nodes that the UE is capable of supporting other UE categories of earlier AS versions, including categories 1 to 5 of Rel-8 and above.

7. A method as claimed in any one of claims 3 to 6, wherein the additional protocol field comprises a one bit indicator, or references a *LegacyCategory* information element.

8. A method as claimed in claim 2, wherein the protocol field comprises a legacy information element that is reused to provide the capability information.

9. A method as claimed in claim 8, wherein the legacy information element comprises an *AccessStratumRelease* information element.

10. A method as claimed in claim 9, wherein the A*ccessStratumRelease* information element comprises an enumerated list of the AS release values supported by the UE.

11. A method as claimed in claim 10, wherein the A*ccessStratumRelease* information element further comprises one or more spare values for use with future AS release values.

12. A method as claimed in any one of claims 8 to 11, wherein the protocol field comprises an *earliestSupported-AS* protocol field, for indicating the earliest access stratum release that defines a low complexity category that is supported by the UE.

13. A method in a target base station during a handover preparation procedure of a user equipment (UE) from a source base station to the target base station, the method comprising the steps of:

receiving a capability container relating to the user equipment (step 401);

interpreting capability information in the capability container to determine the earliest access stratum (AS) version that defines a low complexity user equipment category that is supported by the user equipment (step 403); and

using the result of the interpretation to determine whether the handover operation should be continued with the user equipment (step 405).

14. A method as claimed in claim 13, wherein the interpretation step comprises:

determining if an additional protocol field is present or absent, wherein the additional protocol field provides an indication as to whether the earliest supported AS version is earlier than Release 12.

15. A method as claimed in claim 14, wherein determining the presence of the additional protocol field in the capability information relating to the UE provides an indication that the UE is not capable of supporting other UE categories of earlier AS versions.

16. A method as claimed in claim 15, wherein following a determination that the additional protocol field is present, the method further comprises the step of discontinuing a handover procedure with the UE.

17. A method as claimed in claim 14, wherein determining the absence of the additional protocol field in the capability information relating to the UE provides an indication that the UE is capable of supporting other UE categories of earlier AS versions, including categories 1 to 5 of Rel-8 and above.

18. A method as claimed in claim 17, wherein following a determination that the additional protocol field is absent, the method further comprises the step of continuing a handover procedure with the UE.

19. A method as claimed in any one of claims 14 to 18, wherein the additional protocol field comprises a one bit indicator, or references a *LegacyCategory* information element.

20. A method as claimed in any one of claims 13 to 19, wherein absence of a particular protocol field indicates that the UE can support all categories from a predetermined version of the RRC protocol and above.

21. A user equipment (700) comprising:

a processor module (701); and

a protocol field module (703);

wherein the protocol field module is adapted to provide capability information in a capability container relating to the user equipment, wherein the capability information provides an indication of the earliest access stratum (AS) version that defines a low complexity user equipment category that is supported by the user equipment.

22. A user equipment (700) as claimed in claim 21, wherein the processor module (701) is adapted to perform a method as defined in any one of claims 1 to 12.

23. A network node (800) of a communications network, the network node (800) comprising:

a processing module (801);

a receiving module (803) adapted to receive a capability container relating to a user equipment; and

an interpreting module (805) adapted to interpret capability information in the capability container to determine the earliest access stratum (AS) version that defines a low complexity user equipment category that is supported by the user equipment;

wherein the processor module (801) is adapted to use the result of the interpretation module to determine whether a handover operation should be performed with the user equipment.

24. A network node (800) as claimed in claim 23, wherein the processor module (801) is adapted to perform the method steps as defined in any one of claims 13 to 20.

25. A method in a user equipment, the method comprising the step of:

providing a protocol field in a UE-EUTRA-Container to indicate that the UE does not support legacy categories 1, 2, 3, 4 or 5 (step 501); or

providing a protocol field in a UE-EUTRA-Container to indicate that

the UE only supports a low complexity category relating to Release 12 and above (step 601).

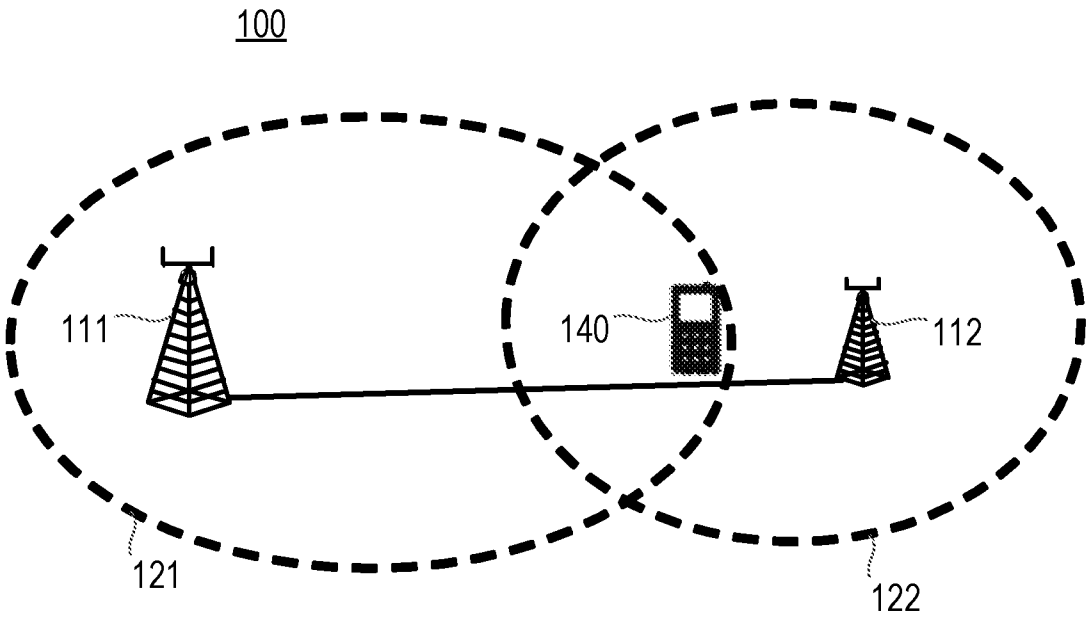

Figure 1

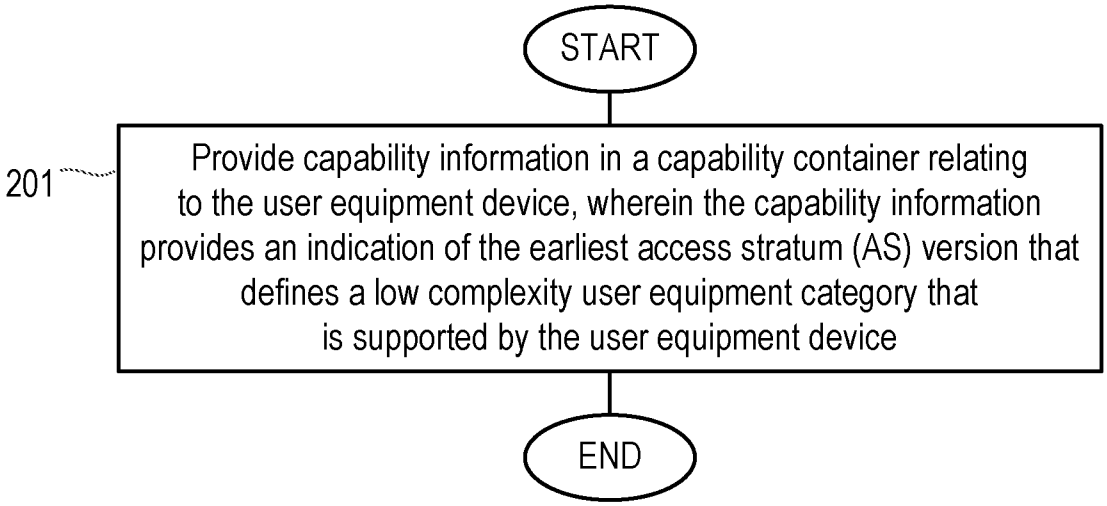

Figure 2

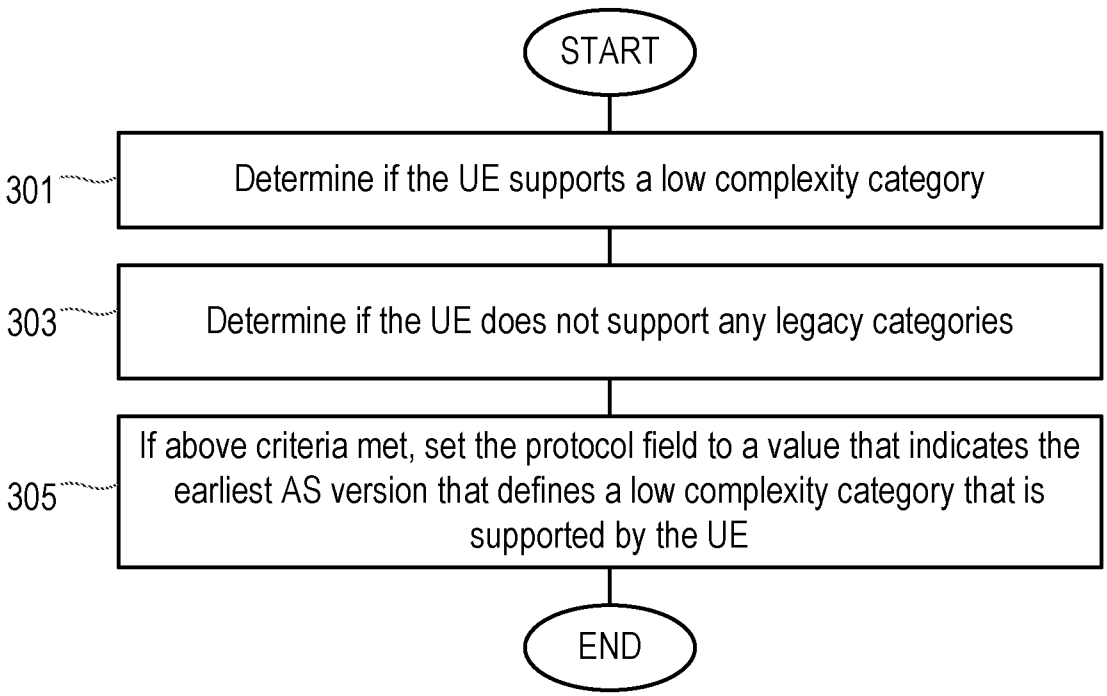

Figure 3

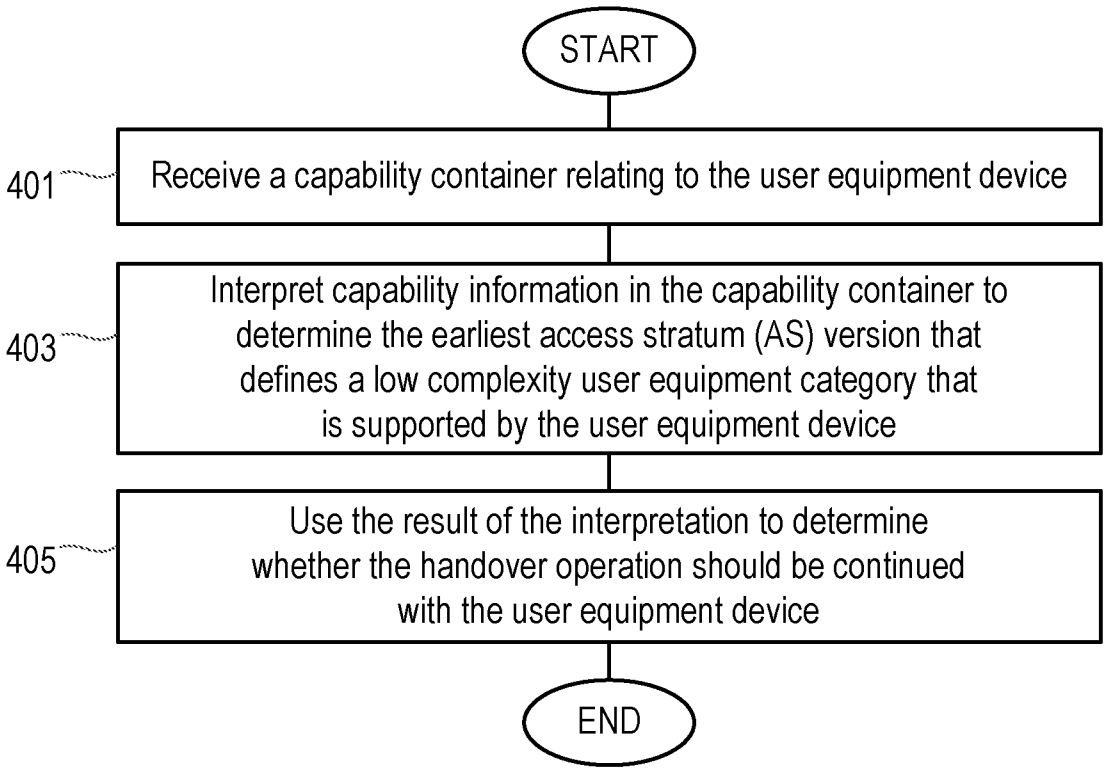
START
401
Receive a capability container relating to the user equipment device
403
Interpret capability information in the capability container to determine the earliest access stratum (AS) version that defines a low complexity user equipment category that is supported by the user equipment device
405
Use the result of the interpretation to determine whether the handover operation should be continued with the user equipment device
END

Figure 4

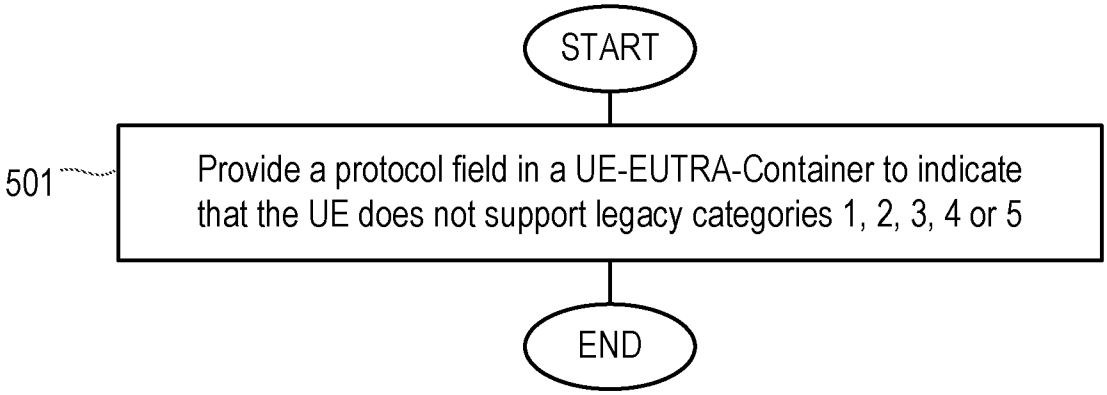

Figure 5

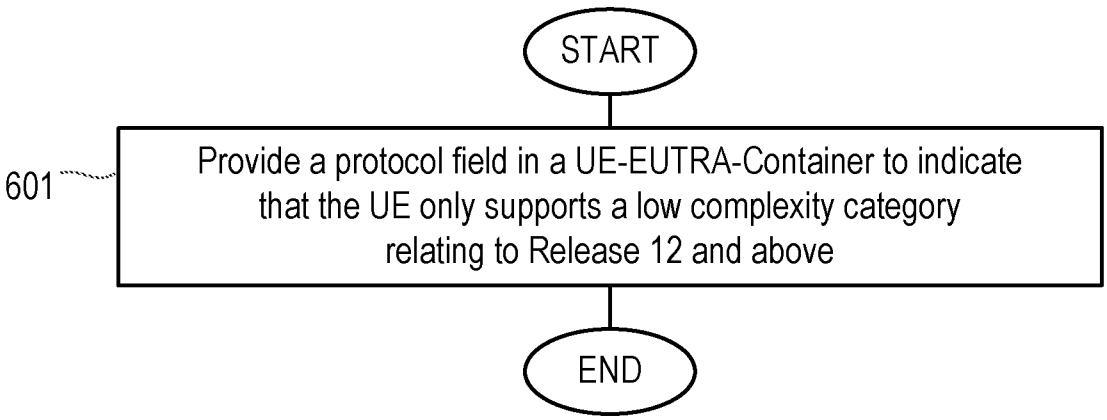

Figure 6

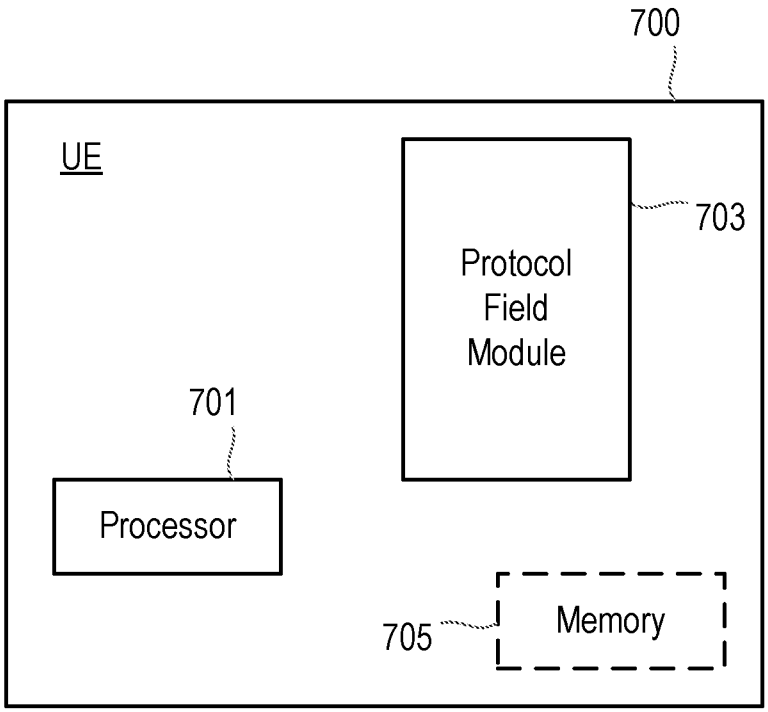

Figure 7

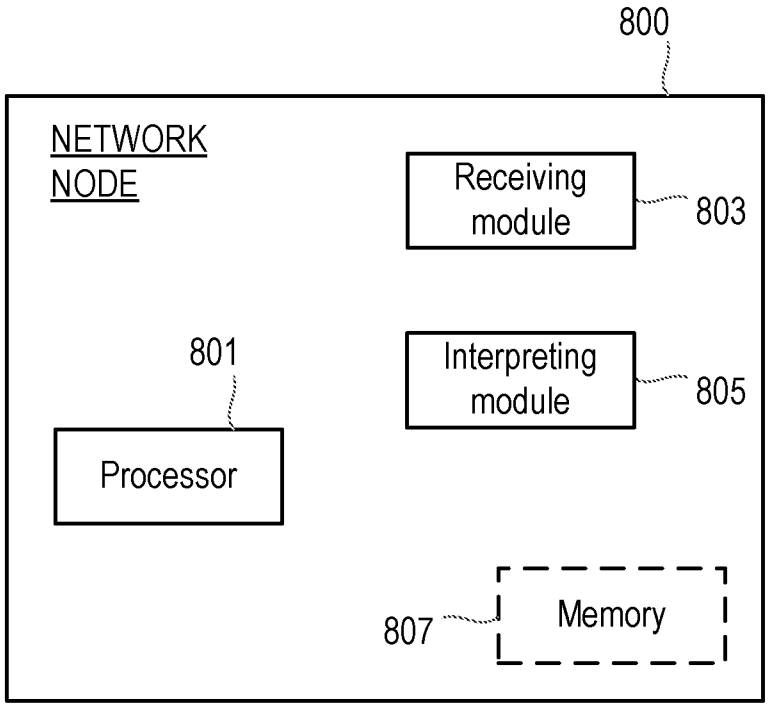
800
NETWORK NODE
Receiving module
803
801
Interpreting module
805
Processor
807
Memory

Figure 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2015/050512

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 20130083753 A1 (LEE MOON-IL ET AL), 4 April 2013 (2013-04-04); paragraph [0374] --	1-25
A	3GPP TSG-RAN WG2 #85; R2-140964; Prague, Czech Republic, 10-14 Feb, 2014; Huawei, HiSilicon; Introduction of Category 0 for low cost MTC; Published: 2014-02-14; whole document --	1-25
P, X	3GPP TSG-RAN WG2 #86; R2-142120; Seoul, South Korea, 19th - 23rd May, 2014; Ericsson; Handling of low complexity UE categories during handover; Published: 2014-05-18; whole document -- --------	1-25

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12-10-2015	12-10-2015

Name and mailing address of the ISA/SE	Authorized officer
Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86	Anna Lindgren Telephone No. + 46 8 782 28 00

Form PCT/ISA/210 (second sheet) (January 2015)

International application No.
PCT/SE2015/050512

Continuation of: second sheet
International Patent Classification (IPC)
H04W 36/00 (2009.01)

US	20130083753	A1	04/04/2013	CA	2850569	A1	04/04/2013
				CN	103999528	A	20/08/2014
				EP	2761955	A1	06/08/2014
				JP	2014531856	A	27/11/2014
				KR	20140071480	A	11/06/2014
				TW	201330558	A	16/07/2013
				WO	2013049768	A1	04/04/2013