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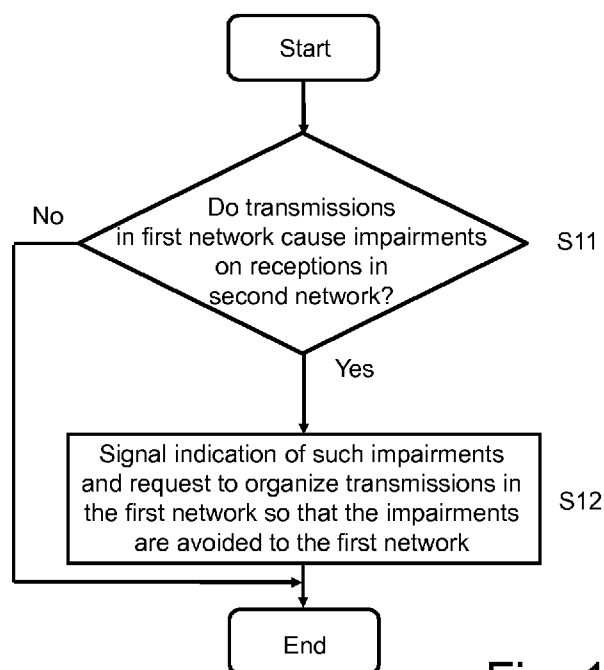


Fig. 1B

(57) Abstract: An apparatus and a method are described, wherein the apparatus is, for example, a user equipment, and comprises a transmission unit capable of transmitting via a first radio network, and a reception unit capable of receiving from at least one second radio network which is different from the first radio network, wherein the apparatus detects whether un-organized transmissions in the first radio network cause or are expected to cause impairments on reception from the at least one second radio network, and signals to the first radio network, an indication of such impairments on reception of the at least one second radio network and a request to organize transmission between the apparatus and the first radio network such that the impairments are avoided, when it is detected that such impairments are caused.

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SIGNALING OF RF IMPAIREMENTS FOR A RECEIVER CAUSED BY SIMULTANEOUS UPLINKS

5 Field of the Invention

The present invention relates to an apparatus, a method and a computer program product by which signaling of RF impairments for a receiver caused by simultaneous uplinks is enabled.

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Related background Art

The following meanings for the abbreviations used in this specification apply:

15	eNB	LTE base station
	EN-DC	EUTRA-NR Dual Connectivity
	gNB	NR base station
	GPS	Global Positioning Service
	IIOT	Industrial Internet of Things
20	LTE	Long Term Evolution
	NFC	Near Field Communication
	NR	New Radio (=5G)
	OFDMA	Orthogonal Frequency Division Multiple Access
	RAN1	Radio Access Network Working Group in 3GPP (RAN1, RAN2,
25		RAN3, RAN4)
	RAT	Radio Access Technology
	Rel	3GPP Release
	RF	Radio Frequency
	SC-FDMA	Single Carrier Frequency Division Multiple Access
30	SUO	Single Uplink Operation
	TDM	Time Division Multiplexing
	UE	User Equipment (= terminal)

V2X Communication between vehicles and other vehicles, or infrastructure

WLAN Wireless Local Area Network (IEEE 802.11)

5 Embodiments of the present invention, although not limited to this, relate to cellular and mobile communication systems such as LTE or new radio (NR). There are multiple methods proposed and also specified, where a UE simultaneously connects to multiple cells transmitting multiple uplink signals simultaneously.

10

Concrete examples for simultaneous uplinks are:

- Interband Carrier Aggregation (Rel11 LTE, Rel15 NR):

15 the UE simultaneously transmits uplinks signals on multiple carriers to the same eNB/gNB.

- Dual Connectivity (Rel12 LTE, Rel15 EN-DC):

The UE transmits multiple uplink signals on multiple carriers to two different eNBs/gNBs.

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- Dual Connected handover (Rel16 LTE, Rel16 NR)

25 There are currently two Rel 16 work items for mobility enhancements, one for LTE and one for NR. One of the key targets is to reduce the handover interruption time to zero milliseconds (in NR), or at least as close as possible to 0ms. This can only be achieved by setting up the target cell before detaching from the source cell. Hence, for a short time, the UE will be simultaneously connected to both, source and target cells, as described in R2-1814460, "The analysis of LTE mobility interruption and possible enhancement directions", Nokia, for example.

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Those methods have been specified or discussed since they provide significant benefits in terms of throughput, interruption and/or robustness.

However, such approaches might have an impact on other transmission channels of an UE in case the UE has ongoing transmissions via a different network.

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Summary of the Invention

Embodiments of the present invention address this situation and aim to provide measures ensuring an operation of other transmission of a UE.

10

According to a first aspect, an apparatus is provided which comprises a transmission unit capable of transmitting via a first radio network, a reception unit capable of receiving from at least one second radio network which is different from the first radio network, and at least one processor and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to perform: detecting whether un-organized transmissions in the first radio network cause or are expected to cause impairments on reception from the at least one second radio network, and signaling, from the apparatus to the first radio network, an indication of such impairments on reception of the at least one second radio network and a request to organize transmission between the apparatus and the first radio network such that the impairments are avoided, when it is detected that such impairments are caused.

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According to a second aspect, a method, for a user equipment method is provided, wherein the user equipment comprises a transmission unit capable of transmitting via a first radio network and a reception unit capable of receiving from at least one second radio network which is different from the first radio network, the method comprising:

30

detecting whether un-organized transmissions in the first radio network cause or are expected to cause impairments on reception from the at least one second radio network, and

signaling, from to the first radio network, an indication of such impairments on reception of the at least one second radio network and a request to organize transmission between the user equipment and the first radio network such that the impairments are avoided, when it is detected that
5 such impairments are caused.

The first and second aspects may be modified as follows:

The transmission via the first radio network may comprise transmission of
10 multiple uplink signals to multiple cells of the first radio network.

The signaling may comprise frequency information indicating a frequency of the second radio network on which an impairment due to transmission in the first radio network is caused.
15

The frequency information may comprise the frequency as a center frequency and a bandwidth of a signal of the second radio network which cannot be received because of the impairment due to transmission in the first radio network.
20

The request may contain a proposal for overcoming the impairments.

The proposal may contain at least one of the following:

- applying a time division multiplex scheme taking into account the
25 transmissions on the multiple uplinks in the first radio network such that the multiple uplinks in the first radio network are not sent at the same time, and
- shutting down a frequency used by the second radio network.

The first radio network and the at least one second radio network may
30 comprise different radio access technologies.

The apparatus or user equipment may perform the detection whether transmissions in the first radio network may cause impairments on

transmissions in the at least one second radio network, when receiving an instruction to set up additional connections in the first radio network and/or when setting up a connection in the at least one second radio network.

- 5 Moreover, an indication may be sent to the first radio network that the un-organized transmission to the first radio network is no longer expected to cause impairments to the second radio network such that the network may fall back to the un-organized transmission.
- 10 Furthermore, a transmission in the second network impaired by the transmission in the first network may be deactivated in case no response to the request is received from the first network or an indication is received that the first radio network cannot solve the problem.
- 15 The transmission unit may be capable of sending simultaneous uplinks via the first radio network, and an impairment on a reception in the second radio network is caused by an intermodulation interference created by simultaneous uplinks.
- 20 According to a third aspect, an apparatus, being a network control element in a first radio network, is provided which comprises: at least one processor and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to perform: receiving signaling, from
- 25 a user equipment, including an indication that un-organized transmissions in the first radio network cause or are expected to cause impairments on receptions from at least one second radio network to which the user equipment is connected and a request to organize transmission between the user equipment and the first radio network such that the impairments are
- 30 avoided, and organizing transmission between the user equipment and the first radio network based on the received signaling.

According to a fourth aspect, a method for a network control element in a first radio network is provided which comprises:

receiving signaling, from a user equipment, including an indication that un-organized transmissions in the first radio network cause or are expected to cause impairments on receptions from at least one second radio network to which the user equipment is connected and a request to organize transmission between the user equipment and the first radio network such that the impairments are avoided, and

organizing transmission between the user equipment and the first radio network based on the received signaling.

The third and fourth aspects may be modified as follows:

The transmission via the first radio network may comprise the transmission of multiple uplink signals to multiple cells of the first radio network.

The signaling may comprise frequency information indicating a frequency of the second radio network on which an impairment due to transmission in the first radio network is caused.

The frequency information may comprise the frequency as a center frequency and a bandwidth of a signal of the second radio network which cannot be received because of the impairment due to transmission in the first radio network.

The request may contain a proposal for overcoming the impairments.

The proposal may contain at least one of the following:

- applying a time division multiplex scheme taking into account the transmission in the first radio network and the transmission in the second radio network such that uplinks in the first radio network are not sent at the same time as uplinks in the second radio network, and

- shutting down a frequency used by the second radio network.

The first radio network and the at least one second radio network may comprise different radio access technologies.

- 5 Moreover, the apparatus or the network may receive an indication from the user equipment that the un-organized transmission to the first radio network is no longer expected to cause impairments to the second radio network, and may fall back to the un-organized transmission between the user equipment and the first radio network based on the indication.

10

- According to an fifth aspect of the present invention a computer program product is provided which comprises code means for performing a method according to any one of the second and fourth and/or their modifications when run on a processing means or module. The computer program product may be embodied on a computer-readable medium, and/or the computer program product may be directly loadable into the internal memory of the computer and/or transmittable via a network by means of at least one of upload, download and push procedures.

- 20 According to an sixth aspect an apparatus is provided which comprises means for transmitting via a first radio network, means for receiving from at least one second radio network which is different from the first radio network, and means for detecting whether un-organized transmissions in the first radio network cause or are expected to cause impairments on reception from the at least one second radio network, and means for signaling, from the apparatus to the first radio network, an indication of such impairments on reception of the at least one second radio network and a request to organize transmission between the apparatus and the first radio network such that the impairments are avoided, when it is detected that such impairments are caused.
- 25
- 30

According to an seventh aspect, an apparatus is provided which comprises means for receiving signaling, from a user equipment, including an indication

that un-organized transmissions in the first radio network cause or are expected to cause impairments on receptions from at least one second radio network to which the user equipment is connected and a request to organize transmission between the user equipment and the first radio network such that the impairments are avoided, and means for organizing transmission between the user equipment and the first radio network based on the received signaling.

The sixth and seventh aspects may be modified similar as the first and third aspects.

Brief Description of the Drawings

These and other objects, features, details and advantages will become more fully apparent from the following detailed description of embodiments of the present invention which is to be taken in conjunction with the appended drawings, in which:

Fig. 1A shows a UE 1 according to an embodiment,

Fig. 1B shows a procedure carried out by the UE 1 according to an embodiment,

Fig. 2A shows an eNB 2 according to an embodiment,

Fig. 2B shows a procedure carried out by the eNB 2 according to an embodiment,

Fig. 3 illustrates EN-DC with a single uplink operation,

Fig. 4 illustrates dual handover with a single uplink operation, and

Fig. 5 shows an example in which two uplinks of the UE 1 to two cells of a first radio network cause interference on reception from a second radio network.

5

Detailed Description of embodiments

In the following, description will be made to embodiments of the present invention. It is to be understood, however, that the description is given by way of example only, and that the described embodiments are by no means to be understood as limiting the present invention thereto.

Before describing embodiments in detail, the problem underlying the present application is described in some more detail. As mentioned above, currently there are several approaches in which simultaneous uplinks are applied, for example Interband Carrier Aggregation, Dual Connectivity and Dual Connected handover. These approaches provide significant benefits in terms of throughput, interruption and/or robustness.

For many of those methods it is likely that two transmitter chains are needed in the terminal. However, even with two individual transmitter chains, RF impairments might be created, in particular intermodulation products. Due to the extremely small size of the terminals, there will be a lot of undesired coupling of signals. For instance, output of one power amplifier can couple to input or output of another power amplifier, even though they are not connected by intention, which leads to creating unwanted intermodulation products. Furthermore, these intermodulation products may couple accidentally into receivers inside the same terminal. If the frequency of the intermodulation products (which is typically a linear combination of the frequencies of the involved SC-FDMA / OFDMA signals) coincide with the frequency of a signal that shall be received by the terminal, then it is possible that this signal cannot be detected. Hence the reception is disturbed by the own RF impairments.

It is important to mention that today's terminal support a multitude of radio access technologies (RATs), e.g. 2G, 3G, LTE, NR, Bluetooth, WLAN, NFC, GPS. Extending the view from smartphones to V2X devices (e.g. cars), or IIoT devices, even more RATs may come into play, including proprietary ones. That is, a terminal may have to receive many different signals at different frequencies, and the mobile network is not necessarily aware which RATs are implemented in a terminal, and it may not know whether an implemented RAT has to be received at a given point in time, and at which frequency.

10

Today, RAN4 specifies the necessary regulatory requirements that guarantees protection to some radio systems but not all. For example, there is no protection requirements for GPS or ISM band (WLAN and BT). Typically, RAN4 specifies protection only against other 3GPP bands and even in this case the specified protection level guarantees only that other terminals are not interfered, the protection level is not sufficient for own reception protection.

15

This creates multiple problems:

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a) These requirements do not cover problems which occur inside the device due to undesired RF coupling. Note that the mentioned RF impairments also occur outside the device. But because interference maybe filtered out before transmission over the antenna, and with the help of propagation loss between terminals these signals are not an issue.

25

b) So far, simultaneous uplinks are only specified for transmission in different carriers. With the dual connected handover, we may get a feature with simultaneous uplinks on the same carrier. Assuming SC-FDMA on the uplink, this may create more diverse intermodulation products, e.g. at very low frequency bands. Although intra-band uplink CA is quite similar from interference point of view.

30

c) With more and more technologies coming up, and with more and more frequency bands which are allocated for LTE/NR, the possible combinations and RF impairments grow massively such that RAN4 may no longer handle the current approach, especially as for NR NSA (EN-DC) two uplinks are the mandatory requirement.

In EN-DC, if intermodulation interference to own downlink PCell reception is identified by 3GPP, then it is specified that UE may request single uplink operation SUO for that uplink band combination by indicating that it does not support simultaneous uplink via UE capabilities (this is discussed below in more detail).

For instance, there is a band combination where the LTE band 3 uplink uses ~1.8GHz and the NR band 77 or 78 uplink uses 3.5GHz. The intermodulation product lands at 1.7GHz (the difference between the transmitted frequencies), which exactly coincides with the LTE band 3 downlink. For this example (and many others), 3GPP RAN4 has specified an allowed sensitivity degradation for the LTE band. As an alternative method, a solution was defined which avoids the intermodulation products by using non-overlapping TDM patterns for the uplinks, i.e., SUO. In other words, the LTE and the NR uplinks are transmitted alternately, and never simultaneously. This protects the downlink transmission, but still allows to use LTE as a (mobility) anchor for the connection, and to get the huge NR throughput at the same time.

Fig. 3 illustrates a Single Uplink Operation with EN-DC in a synchronous network, i.e., the SUO for EN-DC. The UE is connected to a LTE Master eNB and to a NR Secondary gNB. The Master eNB signals a TDM pattern to the UE (it uses the existing TDD patterns). Transmission is organized such that the UE uses the uplink subframes in the TDD pattern for transmitting uplink to the LTE Master eNB, and the remaining subframes for transmitting uplink to the NR Secondary gNB. Note that LTE Master eNB and NR Secondary gNB can use the downlink continuously.

It has to be clearly mentioned that those solutions will always cause some disadvantages, for example, they may sacrifice performance and/or create some complexity.

- 5 Similar TDM solutions might be proposed for the dual connected handover. Fig. 4 illustrates how a SUO for dual connected handover may look like. Uplink transmission is organized such that, e.g., subframes 1,2,5,6,7,10 are sent to the target cell, and subframes 3,4,8,9 are sent to the source cell. This reveals also the drawbacks: for instance, since re-transmissions have to happen on
- 10 the same connection as the first transmission, they will get delayed by the TDM pattern.

36.331 has specified an in-device coexistence (IDC) indication. Under certain circumstances, the UE can report co-existence problems to the network:

- 15 • When the "victim" (i.e., a network connection which may be impaired) is a RAT for which a measurement object was defined (i.e. if it is a (E-)UTRA or an NR carrier)
- Even when the victim is not a 3GPP RAT, the UE can indicate when an IDC problem was created by RATs for which measurement objects are
- 20 defined.

In the latter case, the UE would indicate that one or two measurement objects are creating IDC problems. However, the network still would not know

- The frequency of the victim (without the victim frequency, the network
- 25 will not understand what type of IDC problem is created by the (aggressor) frequencies of the measurement objects, in particular it cannot understand that it is an intermodulation problem)
- In principle, the network would not know which part of the measurement object is causing the problem (uplink or downlink frequency).
- 30 • The network would also not know that single uplink operation would solve it.
- Certainly, the case of dual connected handover is not covered in the current spec. Straight forward extension would be to allow the UE to indicate

the measurement object corresponding to the carrier frequency that are associated with dual connected handover. However, in this case, the network cannot know whether it is the uplink itself generating problems, or only the combination of 2 uplinks.

5

Hence, the current IDC indication (or simple extensions thereof) would not solve the problem.

10 In the following, UE capabilities are described. In particular, not all UEs support simultaneous uplinks. When negotiating the UE capabilities during EN-DC setup, the UE can signal that it does not support simultaneous uplinks, thereby requesting single uplink operation.

15 However, the UE is only allowed so signal this for certain band combinations specified in 36.101-3, for which the downlink would be interfered too much. UE capabilities cannot be abused for other cases than specified in the spec. Furthermore, this will have a rather static impact. Once the EN-DC is setup with simultaneous uplinks, the UE can certainly not change its capability (if an IDC problem arises). Vice versa, once the EN-DC is setup with single
20 uplink, the UE cannot upgrade to simultaneous uplinks (if an IDC problem disappears).

So, the UE capabilities will also not solve the problem that simultaneous uplinks may create intermodulation interference to an unexpected RAT which
25 is not covered by 3GPP.

Some embodiments of the present application aim to overcome the above problem.

30 In the following, a general overview of some embodiments is described by referring to Figs. 1A, 1B, 2A and 2b.

In particular, Fig. 1A shows an UE 1 as an example for a first apparatus

according to the present embodiment. However, the invention is not limited to an UE, but can be any kind of terminal device. Fig. 1B illustrates a process carried out by the UE 1.

5 The UE 1 comprises at least one processor 11, at least one memory 12 including computer program code, a transmission unit 13 which is capable of transmitting via a first radio network, and a reception unit 14 capable of receiving from a second radio network which is different from the first radio network. The at least one processor 11, with the at least one memory 12 and
10 the computer program code, is configured to cause the apparatus to perform: detecting whether un-organized transmissions in the first radio network cause or are expected to cause impairments on reception from the at least one second radio network (as shown in S11 in Fig. 1B), and, when it is detected that such impairments are caused (Yes in S11), signaling, from the apparatus
15 to the first radio network, an indication of such impairments on reception of the at least one second radio network and a request to organize transmission between the apparatus and the first radio network such that the impairments are avoided (as shown in S12 in Fig. 1B).

20 Fig. 2A shows an eNB 2 as an example for a second apparatus according to the present embodiment. However, the invention is not limited to an eNB, but can be any kind of network control element, for example a base station. For example, in NR, the apparatus may be a gNB. Fig. 1B illustrates a process carried out by the eNB 2.

25 The eNB 2 comprises at least one processor 21 and at least one memory 22 including computer program code. The at least one processor 21, with the at least one memory 22 and the computer program code, is configured to cause the apparatus to perform: receiving signaling, from a user equipment (e.g.
30 UE 1), including an indication that transmissions in the first radio network cause impairments on transmissions in at least one second radio network to which the user equipment is connected and a request to organize transmission between the user equipment and the first radio network such

that the impairments are avoided (as shown in S21 of Fig. 2B), and changing transmission between the user equipment and the first radio network based on the received signaling (as shown in S21 of Fig. 2B).

- 5 The eNB 2 may further comprise a transceiver unit 23 which is capable of transmitting and receiving via a first radio network, and, for example, providing a connection with the UE 1.

Thus, according to some embodiments of the present application, the UE 1
10 detects whether there are impairments of reception in the second radio network due to transmissions in the first radio network. If so, the UE 1 informs the eNB 2 about this and requests the eNB 2 to organize transmission in the first network correspondingly.

- 15 In this way, the eNB 2 is informed about impairments in a second radio network, which the eNB 2 is not aware of. Hence, the impairments can be overcome.

The un-organized transmissions as defined above mean transmissions before
20 they are organized in the first network. In other words, the un-organized transmissions are the original transmissions as controlled or set by the first network without considering possible impairments on receptions in the second network.

- 25 The transmissions in the first radio network mentioned above may be uplink connections from the UE 1 to the eNB 2, for example. In particular, these transmissions may be simultaneous uplinks, wherein the simultaneous uplinks may cause the impairments (e.g., due to intermodulation interferences thereof).

30

The first radio network may be a mobile network (e.g., LTE, NR etc.), and the second network may be WLAN, BT, NFC or another mobile network or the like.

As mentioned above, the UE may be connected to the radio network by multiple uplink connections, wherein the uplinks are sent to different cells, or even different eNBs. Moreover, the first radio network may also include
5 different RATs, e.g. LTE and NR.

In other words, the first radio network may comprise multiple network nodes (base stations), and these multiple network nodes may use different RATs, e.g. LTE and NR. Furthermore, the UE may simultaneously transmit to
10 multiple of those network nodes.

That is, the first radio network also covers the EN-DC case, where a UE is connected to a LTE eNB and to NR gNB at the same time. In such an example, the first radio network described above includes actually two radio networks,
15 namely an LTE network and a NR network.

The transmission unit 13 of the UE 1 may comprise separate transmitters for the first radio network, for example. In case the transmission unit 13 for the first radio network is capable of sending simultaneous uplinks to multiple cells
20 in the first radio network, this transmission unit may comprise separate transmitters for each uplink.

This is shown in Fig. 5, according to which the UE 1 comprises a transmitter 13A for cell 1 of the first radio network, and a transmitter 13B for a cell 2 of
25 the first radio network. Cell 1 uses an uplink radio frequency unit UL RF1, whereas cell 2 uses an uplink radio frequency unit UL RF2. For example, cell 1 may be controlled by an LTE eNB, whereas cell 2 may be controlled by an NR gNB. The reception unit 14 of the UE 1 is indicated by Rx.

30 As also shown in Fig. 5, the two uplinks Uplink 1 and Uplink 2 cause the impairment on the reception by the reception unit 14 from the second radio network within the UE 1 itself.

Moreover, it is noted that the transmission unit 13 may actually be a transceiver unit capable of transmitting to and receiving from the first radio network, and the reception unit 14 may actually be a transceiver unit capable of transmitting to and receiving from the second radio network.

5

In the following, some embodiments are described in more detail.

As described above, according to some embodiments, the aforementioned problems are solved by introducing a signaling from the UE to the mobile network, as an example for a first radio network, which the terminal can use to indicate whether simultaneous uplinks lead to RF impairments of another radio access technology in the UE, and whether the base station has to organize the transmission such that these problems are avoided.

15 According to a certain embodiment, "organizing the transmission such that these problems are avoided" refers to switching to a TDM-like method, where the uplinks are sent alternately and never exactly at the same time, identical or at least similar to the existing "single uplink operation" in EN-DC (cf. Figs. 3 and 4). With this trick, the uplinks are still present simultaneously, but
20 actual transmission is not simultaneous. In this manner, the benefits of using simultaneous uplinks can no longer be exploited, but the advantage is, that the TDM-like method is only applied when it is really needed as UE informs the mobile network on this.

25 It is noted that the "TDM-like method" mentioned above is only an example for overcoming the RF impairment, and other measures are possible. For example, a predistortion method can also be applied, where the UE applies a joint predistortion, e.g. a linear transmit filter, to the simultaneous uplink signals with the target to minimize the intermodulation products; such a
30 predistortion would also create undesired throughput losses and thus should only be applied when really needed. However, the invention is not limited to this, and any other method could be applied by which the impairment can be overcome and/or avoided.

The signaling may contain a proposal, how the mobile network can solve the problem, e.g. an indication to a feature such as "single uplink operation", or "predistortion", etc. If the victim frequency is under control of the mobile network, the UE may also propose to shut down the victim frequency.

Furthermore, the signaling may contain the (center) frequency and potentially the bandwidth of the victim, i.e. of the signal which cannot be received because of the RF impairments.

The aforementioned signaling may happen in the following situations:

- The UE is connected to a first set of at least one cell, and the mobile network instructs the UE to set up additional connections to further cells including simultaneous uplinks. This is typically done via RRC connection reconfiguration message, e.g. to add an NR cell as secondary gNB (EN-DC), or to early setup a target cell for a dual connected handover.

The UE determines whether simultaneous uplinks (and its intermodulation products) would conflict with the reception of another (currently active) radio access technology. If this is the case, it signals this conflict to the mobile network, and the mobile network can decide to withdraw the instruction (and stay with the first set of at least one cell), or to switch to TDM-like method, e.g. via another RRC connection reconfiguration message. If no conflict is detected, multiple connections are setup according to prior art.

- The UE already has multiple connections, including simultaneous uplinks (e.g. since the UE has not detected conflicts during the setup), but the UE now has to start the reception of the second radio network (e.g. another RAT) which would be impaired by the simultaneous uplinks (e.g. it starts an application which involves the reception of the said RAT). Alternatively, the UE may erroneously have agreed to the simultaneous uplinks and determines the conflict with a running reception of another RAT

only after the conflict has occurred. In these cases, the UE signals this conflict to the mobile network, and the mobile network can decide to stop the multiple connections, or to switch to TDM-like method, e.g. via RRC connection reconfiguration message.

5

- The UE already has multiple connections, and it is already organizing the transmissions to avoid impairment (e.g. by using a TDM-like method since the UE has indicated a conflict during setup), but the UE now determines that the conflict has disappeared (e.g. an application involving the reception of the impaired RAT was stopped). In this case, the UE signals that the conflict has disappeared, and the mobile network can switch back to simultaneous, un-organized uplinks in order to exploit the full benefits of the multiple connections.

- 10
- 15 The signaling may be embedded into the existing framework of "in-device coexistence indication" (e.g. as an appropriate extension).

- If the mobile network does not react appropriately (e.g. it does not support the feature to resolve the problem), it may signal to the UE that it cannot resolve the problem, and the UE can decide to shut down the application using the victim receiver. For example, a transmission of the victim receiver (i.e., a transmission in the second network such as a BT network) impaired by the transmission in the mobile network may be deactivated in case no response to the request is received from the eNB or an indication is received that the mobile network cannot solve the problem.
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- 25

For determining conflicts on the UE side, various procedures are possible. For example, one or more of the following measures could be applied:

- 30
- The UE has implemented certain conditions for any second radio networks, which are not known to the mobile network. For instance, the UE could implement a logic indicating a conflict when NFC is running (or has to be started) while a certain 3GPP method is using simultaneous uplinks in

specific bands. This would be in principle hard coded lookup tables.

- The UE may calculate online whether the RF impairments would coincide with a reception of the second radio network. The terminal is aware of the frequencies of the involved simultaneous uplinks f_1 and f_2 , and it is aware of the frequency f_v of the potential victim RAT. Then it may for instance check whether there are small enough constants A_1 and A_2 fulfilling the equation:

$$A_1 * f_1 + A_2 * f_2 = f_v$$

- In principle, the UE may also implement a measurement of the impairments, i.e. it may agree to the setup of multiple connections including simultaneous uplinks, and "complains" only when it measures RF impairments.

In the following, some examples involving two different kinds of networks are described.

Example 1: Dual Connected Handover and NFC

For the LTE work item "Even further Mobility Enhancements", it is currently discussed to setup the target cell before detaching from the source cell, and having both connections for a moment simultaneously. Sending two LTE uplink signals (SC-FDMA) simultaneously, can easily create an intermodulation product around 13MHz which is the frequency used for Near Field Communication (NFC). If the UE uses NFC (e.g. for payment services), such a service may get unstable (and thereby risky) when simultaneous LTE uplinks are used. So, the simultaneous uplinks would create quite some harm.

On the other hand, NFC services are not permanently used. Some UEs may never use NFC services. Others may use NFC services, but rarely. And the mobile network is not aware whether the UE is using an NFC service. It is

noted again that this example cannot be resolved by the existing IDC indication, as discussed above.

Example 2: Bluetooth

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For WLAN, a lot of interaction between WLAN and the mobile network has been specified in 3GPP. However, there is still no interaction with Bluetooth, i.e. the mobile network is completely unaware whether Bluetooth is used or not. With the new frequency bands (e.g. 3.5GHz, 5GHz, 7GHz etc.) it is not
10 unlikely that RF impairments will fall into the Bluetooth bands. So, it would be very helpful for the mobile network to understand whether or not there is currently an impairment.

Example 3: GPS

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GPS band L1 (1 575,42 MHz) is located in a frequency range that can be easily interfered by intermodulation products of dual uplink transmission. Furthermore, as GPS signal level is extremely low it is very susceptible to any
interference.

20

The following advantages can be achieved by the measures as defined in then embodiments described above.

A main advantage is that the TDM-like methods (or other methods for
25 overcoming/avoiding the RF impairments) do not always have to be used if there potentially could be a problem with the RF impairments in a certain band.

Furthermore, standardization does not have to pro-actively solve all possible
30 problems, not knowing whether they occur or not (and how likely they are).

Verticals, i.e. third companies which are using the mobile network of an operator to offer services (as a "tenant") can implement different radio access

technologies in the UEs, even when not covered by 3GPP. This includes proprietary ones and maybe secret ones. This could be interesting for industrial IOT. Today, they can do this as well, but they may not be able to benefit from multiple connections. According to certain embodiments, they can indicate to the mobile network that TDM-like methods or other measures for overcoming the RF impairment shall be used.

Embodiments of the present invention can be applied to LTE, NR; as well as to any other mobile communication system.

Names of network elements, protocols, and methods are based on current standards. In other versions or other technologies, the names of these network elements and/or protocols and/or methods may be different, as long as they provide a corresponding functionality.

In general, the example embodiments may be implemented by computer software stored in the memory (memory resources, memory circuitry) 12, 22 and executable by the processor (processing resources, processing circuitry) 11, 21 or by hardware, or by a combination of software and/or firmware and hardware.

As used in this application, the term "circuitry" refers to all of the following:

(a) hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry) and

(b) to combinations of circuits and software (and/or firmware), such as (as applicable): (i) to a combination of processor(s) or (ii) to portions of processor(s)/software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions) and

(c) to circuits, such as a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present.

This definition of "circuitry" applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term "circuitry" would also cover an implementation of merely a processor (or multiple processors) or portion of a processor and its (or their) accompanying software and/or firmware. The term "circuitry" would also cover, for example and if applicable to the particular claim element, a baseband integrated circuit or applications processor integrated circuit for a mobile phone or a similar integrated circuit in server, a cellular network device, or other network device.

The terms "connected," "coupled," or any variant thereof, mean any connection or coupling, either direct or indirect, between two or more elements, and may encompass the presence of one or more intermediate elements between two elements that are "connected" or "coupled" together.

The coupling or connection between the elements can be physical, logical, or a combination thereof. As employed herein two elements may be considered to be "connected" or "coupled" together by the use of one or more wires, cables and printed electrical connections, as well as by the use of electromagnetic energy, such as electromagnetic energy having wavelengths in the radio frequency region, the microwave region and the optical (both visible and invisible) region, as non-limiting examples.

The memory (memory resources, memory circuitry) 12, 22 may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory, and non-transitory computer-readable media. The processor (processing resources, processing circuitry) 11, 21 may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on a multi core processor architecture, as non-limiting examples.

It is to be understood that the above description is illustrative of the invention and is not to be construed as limiting the invention. Various modifications and applications may occur to those skilled in the art without departing from the true spirit and scope of the invention as defined by the appended claims.

5

CLAIMS

1. An apparatus comprising
a transmission unit capable of transmitting via a first radio network,
5 a reception unit capable of receiving from at least one second radio network which is different from the first radio network, and
at least one processor and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least
10 to perform:
- detecting whether un-organized transmissions in the first radio network cause or are expected to cause impairments on reception from the at least one second radio network, and
signaling, from the apparatus to the first radio network, an
15 indication of such impairments on reception of the at least one second radio network and a request to organize transmission between the apparatus and the first radio network such that the impairments are avoided, when it is detected that such impairments are caused.
- 20 2. The apparatus according to claim 1, wherein the transmission via the first radio network comprises transmission of multiple uplink signals to multiple cells of the first radio network.
3. The apparatus according to claim 1 or 2, wherein the signaling
25 comprises frequency information indicating a frequency of the second radio network on which an impairment due to transmission in the first radio network is caused.
4. The apparatus according to claim 3, wherein the frequency information
30 comprises the frequency as a center frequency and a bandwidth of a signal of the second radio network which cannot be received because of the impairment due to transmission in the first radio network.

5. The apparatus according to any one of the claims 1 to 4, wherein the request contains a proposal for overcoming the impairments.

6. The apparatus according to claim 5, wherein the proposal contains at least one of the following:

- applying a time division multiplex scheme taking into account the transmissions on the multiple uplinks in the first radio network such that the multiple uplinks in the first radio network are not sent at the same time, and
- shutting down a frequency used by the second radio network.

10

7. The apparatus according to any one of the claims 1 to 6, wherein the first radio network and the at least one second radio network comprise different radio access technologies.

8. The apparatus according to any one of the claims 1 to 7, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to further perform:

performing the detection whether transmissions in the first radio network may cause impairments on transmissions in the at least one second radio network, when receiving an instruction to set up additional connections in the first radio network and/or when setting up a connection in the at least one second radio network.

9. The apparatus according to any one of the claims 1 to 8, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to further perform:

sending an indication to the first radio network that the un-organized transmission to the first radio network is no longer expected to cause impairments to the second radio network such that the network may fall back to the un-organized transmission.

10. The apparatus according to any one of the claims 1 to 9, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to further perform:

5 deactivating a transmission in the second network impaired by the transmission in the first network in case no response to the request is received from the first network or an indication is received that the first radio network cannot solve the problem.

10 11. The apparatus according to any one of the claims 1 to 10, wherein the transmission unit is capable of sending simultaneous uplinks via the first radio network, and an impairment on a reception in the second radio network is caused by an intermodulation interference created by simultaneous uplinks.

15 12. An apparatus, being a network control element in a first radio network, comprising

 at least one processor and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to perform:

20 receiving signaling, from a user equipment, including an indication that un-organized transmissions in the first radio network cause or are expected to cause impairments on receptions from at least one second radio network to which the user equipment is connected and a request to organize transmission between the user equipment and the first radio network such
25 that the impairments are avoided, and

 organizing transmission between the user equipment and the first radio network based on the received signaling.

30 13. The apparatus according to claim 12, wherein the transmission via the first radio network comprises transmission of multiple uplink signals to multiple cells of the first radio network.

14. The apparatus according to claim 12 or 13, wherein the signaling comprises frequency information indicating a frequency of the second radio network on which an impairment due to transmission in the first radio network is caused.

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15. The apparatus according to claim 14, wherein the frequency information comprises the frequency as a center frequency and a bandwidth of a signal of the second radio network which cannot be received because of the impairment due to transmission in the first radio network.

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16. The apparatus according to any one of the claims 12 to 15, wherein the request contains a proposal for overcoming the impairments.

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17. The apparatus according to claim 16, wherein the proposal contains at least one of the following:

- applying a time division multiplex scheme taking into account the transmission in the first radio network and the transmission in the second radio network such that uplinks in the first radio network are not sent at the same time as uplinks in the second radio network, and

20

- shutting down a frequency used by the second radio network.

18. The apparatus according to any one of the claims 12 to 17, wherein the first radio network and the at least one second radio network comprise different radio access technologies.

25

19. The apparatus according to any one of the claims 12 to 18, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to further perform:

- receiving an indication from the user equipment that the un-organized transmission to the first radio network is no longer expected to cause impairments to the second radio network, and

30

- falling back to the un-organized transmission between the user equipment and the first radio network based on the indication.

20. A method, for a user equipment, wherein the user equipment comprises a transmission unit capable of transmitting via a first radio network and a reception unit capable of receiving from at least one second radio network which is different from the first radio network, the method comprising

detecting whether un-organized transmissions in the first radio network cause or are expected to cause impairments on reception from the at least one second radio network, and

signaling, from to the first radio network, an indication of such impairments on reception of the at least one second radio network and a request to organize transmission between the user equipment and the first radio network such that the impairments are avoided, when it is detected that such impairments are caused.

21. The method according to claim 20, wherein the transmission via the first radio network comprises transmission of multiple uplink signals to multiple cells of the first radio network.

22. The method according to claim 20 or 21, wherein the signaling comprises frequency information indicating a frequency of the second radio network on which an impairment due to transmission in the first radio network is caused.

23. The method according to claim 22, wherein the frequency information comprises the frequency as a center frequency and a bandwidth of a signal of the second radio network which cannot be received because of the impairment due to transmission in the first radio network.

24. The method according to any one of the claims 20 to 23, wherein the request contains a proposal for overcoming the impairments.

25. The method according to claim 24, wherein the proposal contains at least one of the following:

- applying a time division multiplex scheme taking into account the transmissions on the multiple uplinks in the first radio network such that the multiple uplinks in the first radio network are not sent at the same time, and
- shutting down a frequency used by the second radio network.

26. The method according to any one of the claims 20 to 25, wherein the first radio network and the at least one second radio network comprise different radio access technologies.

27. The method according to any one of the claims 20 to 26, further comprising:

performing the detection whether transmissions in the first radio network may cause impairments on transmissions in the at least one second radio network, when receiving an instruction to set up additional connections in the first radio network and/or when setting up a connection in the at least one second radio network.

28. The method according to any one of the claims 20 to 27, further comprising:

sending an indication to the first radio network that the un-organized transmission to the first radio network is no longer expected to cause impairments to the second radio network such that the network may fall back to the un-organized transmission.

29. The method according to any one of the claims 20 to 28, further comprising:

deactivating a transmission in the second network impaired by the transmission in the first network in case no response to the request is received from the first network or an indication is received that the first radio network cannot solve the problem.

30. The method according to any one of the claims 20 to 29, wherein the transmission unit is capable of sending simultaneous uplinks via the first radio network, and an impairment on a reception in the second radio network is caused by an intermodulation interference created by simultaneous uplinks.

5

31. An method for a network control element in a first radio network, comprising:

receiving signaling, from a user equipment, including an indication that un-organized transmissions in the first radio network cause or are expected to cause impairments on receptions from at least one second radio network to which the user equipment is connected and a request to organize transmission between the user equipment and the first radio network such that the impairments are avoided, and

10

organizing transmission between the user equipment and the first radio network based on the received signaling.

15

32. The method according to claim 31, wherein the transmission via the first radio network comprises transmission of multiple uplink signals to multiple cells of the first radio network.

20

33. The method according to claim 31 or 32, wherein the signaling comprises frequency information indicating a frequency of the second radio network on which an impairment due to transmission in the first radio network is caused.

25

34. The method according to claim 33, wherein the frequency information comprises the frequency as a center frequency and a bandwidth of a signal of the second radio network which cannot be received because of the impairment due to transmission in the first radio network.

30

35. The method according to any one of the claims 31 to 34, wherein the request contains a proposal for overcoming the impairments.

36. The method according to claim 35, wherein the proposal contains at least one of the following:

- applying a time division multiplex scheme taking into account the transmission in the first radio network and the transmission in the second radio network such that uplinks in the first radio network are not sent at the same time as uplinks in the second radio network, and
- shutting down a frequency used by the second radio network.

37. The method according to any one of the claims 31 to 36, wherein the first radio network and the at least one second radio network comprise different radio access technologies.

38. The method according to any one of the claims 31 to 37, further comprising:

- receiving an indication from the user equipment that the un-organized transmission to the first radio network is no longer expected to cause impairments to the second radio network, and
- falling back to the un-organized transmission between the user equipment and the first radio network based on the indication.

39. A computer program product comprising code means for performing a method according to any one of the 20 to 38 when run on a processing means or module.

40. The computer program product according to claim 39, wherein the computer program product is embodied on a computer-readable medium, and/or the computer program product is directly loadable into the internal memory of the computer and/or transmittable via a network by means of at least one of upload, download and push procedures.

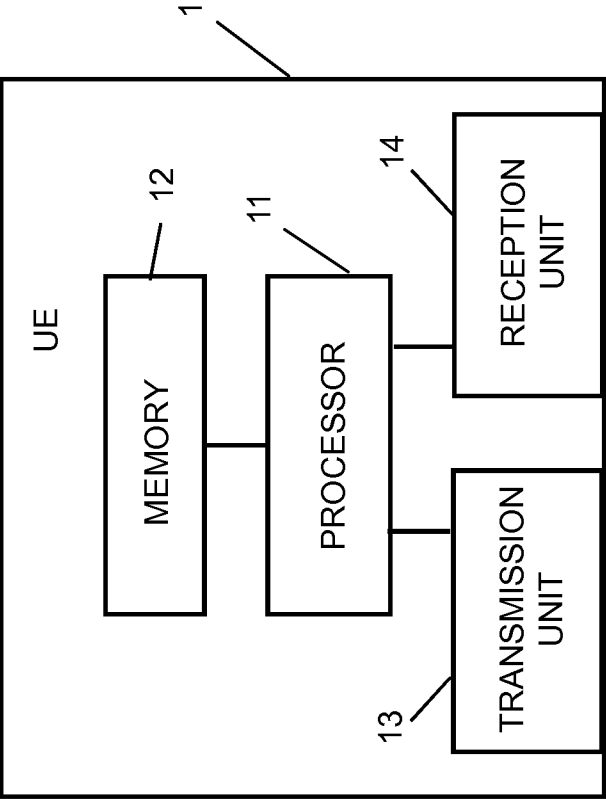


Fig. 1A

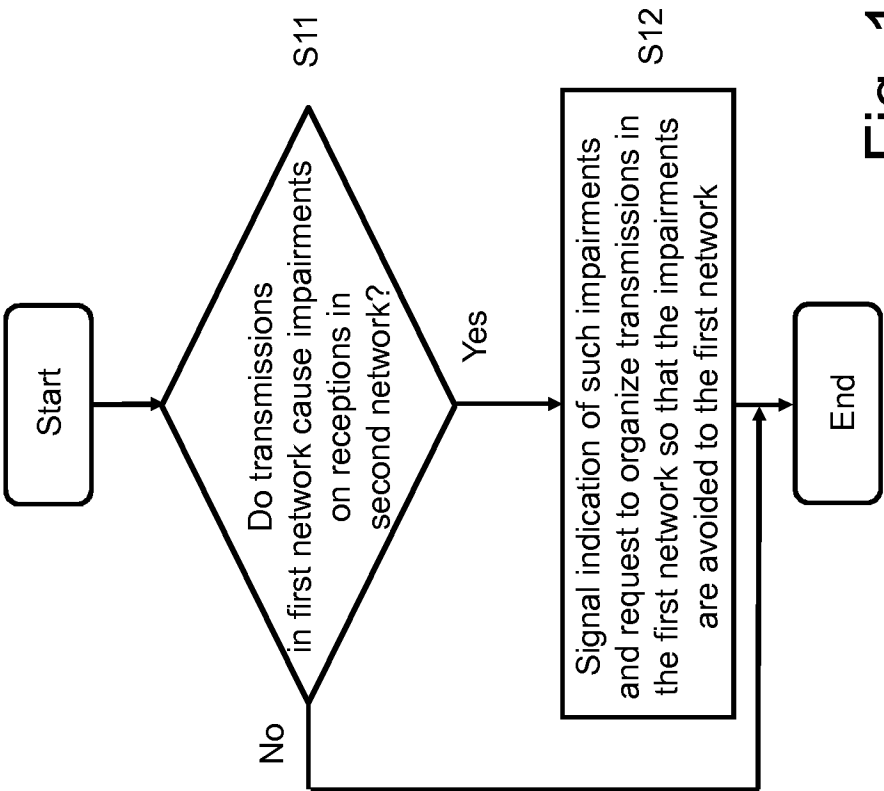


Fig. 1B

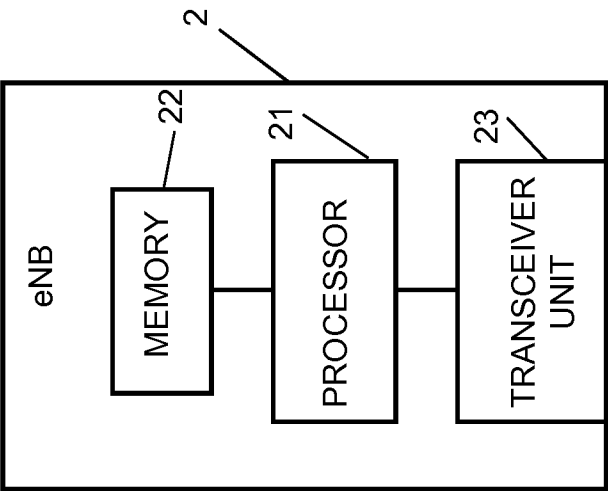


Fig. 2A

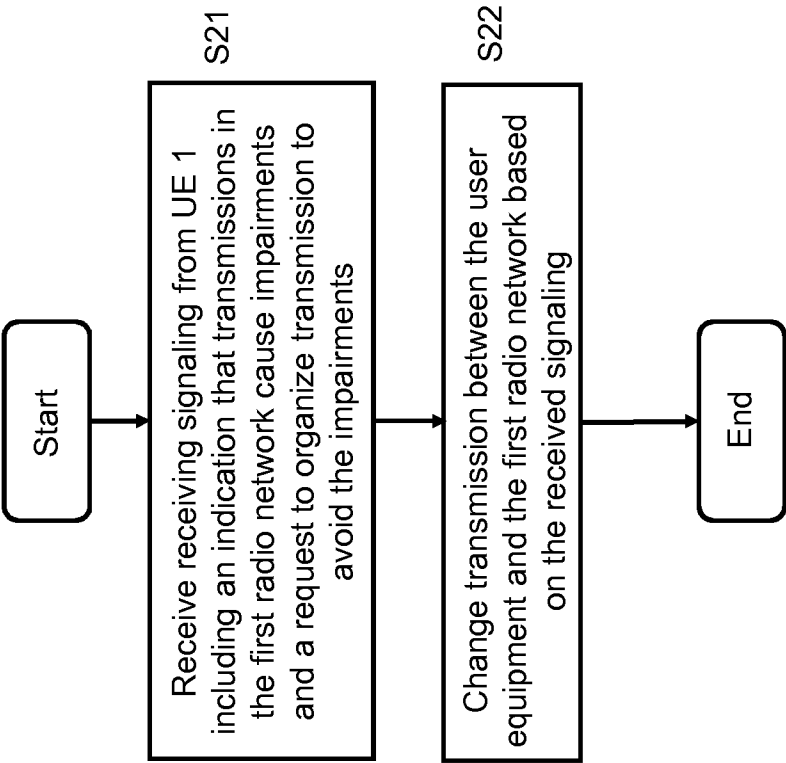


Fig. 2B

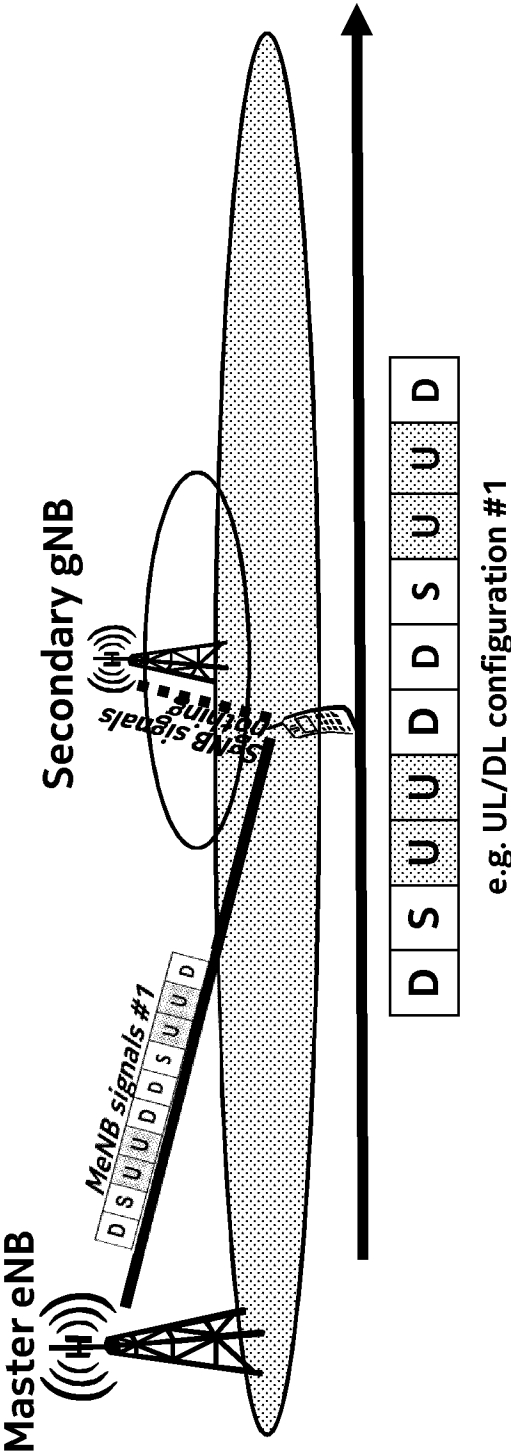


Fig. 3

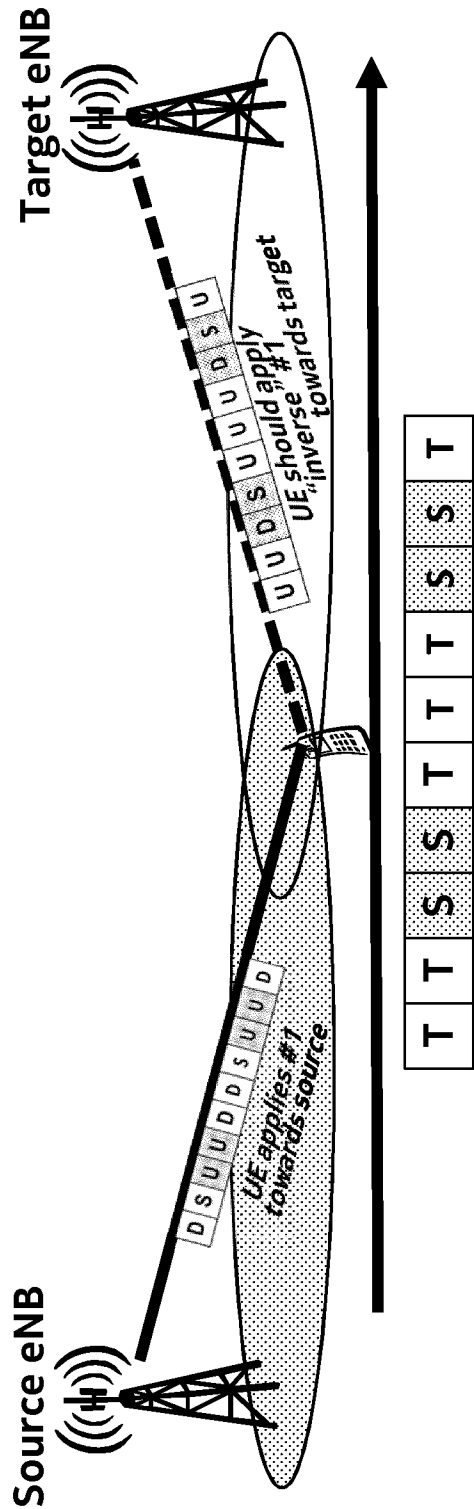


Fig. 4

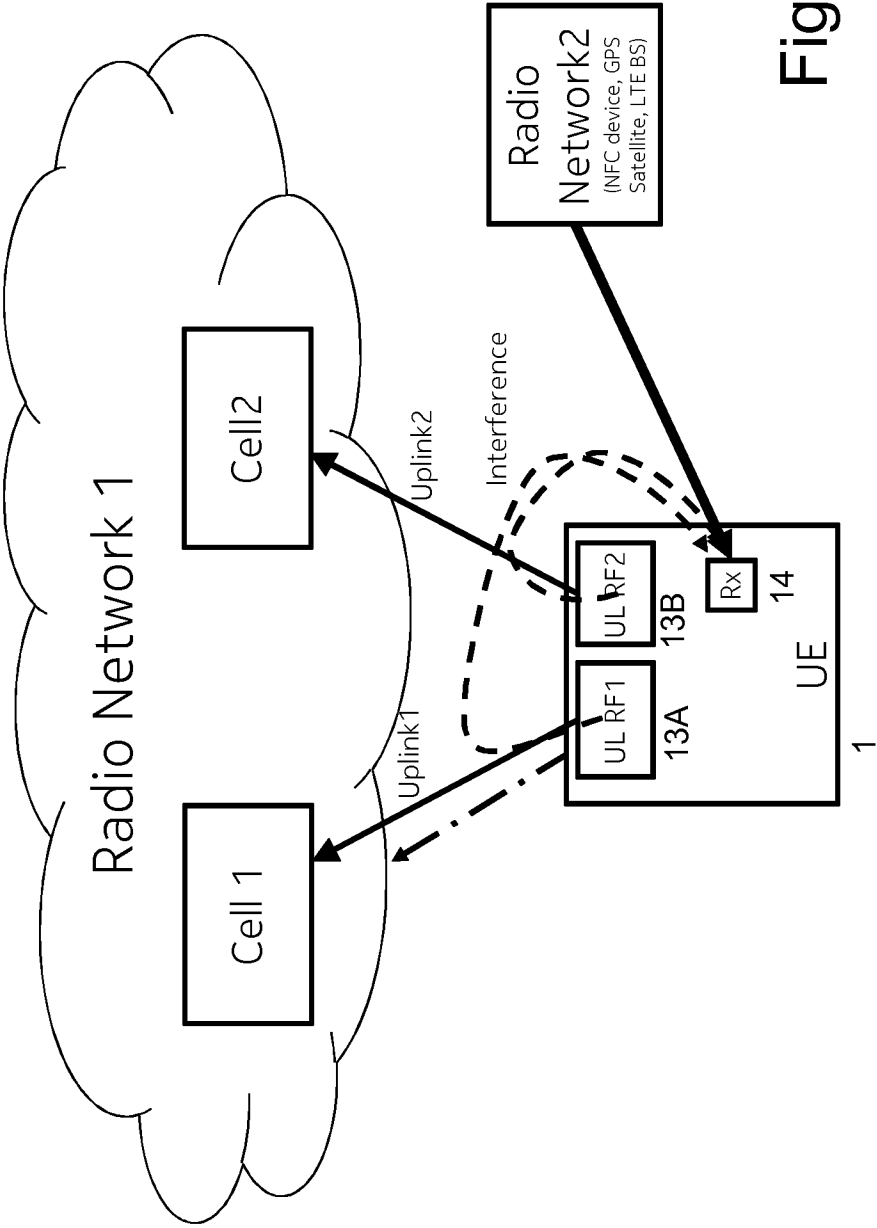


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/053567

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W72/08
ADD.

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)
H04W

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

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

EPO-Internal, WPI Data, COMPENDEX, INSPEC, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/047894 A1 (BROADCOM CORP [US]; ISOKANGAS JARI [FI] ET AL.) 3 April 2014 (2014-04-03) page 3, line 14 - page 6, line 32; figures 1-9 page 8, line 17 - page 32, line 13 -----	1-40
X	US 2012/252442 A1 (FU I-KANG [TW] ET AL) 4 October 2012 (2012-10-04) paragraphs [0003] - [0009], [0020] - [0039]; figures 1-8 -----	1-40



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"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

28 October 2019

Date of mailing of the international search report

15/11/2019

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2019/053567

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