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Rahman et al.

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(54) **SWITCHING OF TRANSMISSION BETWEEN CELL GROUPS**

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(51) **Int. Cl.**
H04W 36/00 (2009.01)
H04W 36/08 (2009.01)
(Continued)

(52) **U.S. Cl.**
CPC ... ***H04W 36/0072*** (2013.01); ***H04W 36/0055*** (2013.01); ***H04W 36/0069*** (2018.08);
(Continued)

(58) **Field of Classification Search**
None
See application file for complete search history.

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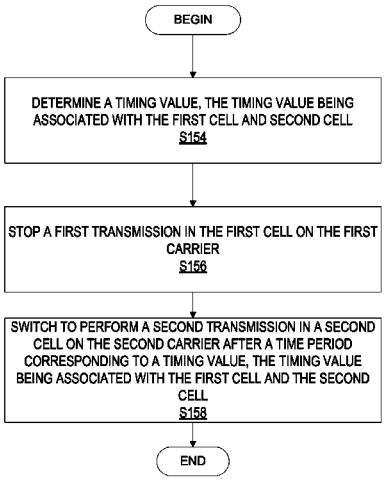
(57) **ABSTRACT**

A method, system and apparatus for switching of a transmission between cell groups. According to one aspect of the disclosure, a network node is configured to provide a first cell on a first carrier and to communicate with a wireless device where the first cell is part of a first cell group is provided. The network node includes processing circuitry configured to: receive a transmission from a wireless device after a time period following a switching of a transmission from a second cell being part of a second cell group, the first cell group being different from the second cell group; and determine a timing value corresponding to the time period, the time value being associated at least in part with the second cell group.

12 Claims, 14 Drawing Sheets



(51) **Int. Cl.**
H04W 36/36 (2009.01)
H04W 56/00 (2009.01)
H04W 72/0446 (2023.01)

(52) **U.S. Cl.**
CPC ***H04W 36/08*** (2013.01); ***H04W 36/36*** (2013.01); ***H04W 56/0005*** (2013.01); ***H04W 56/0045*** (2013.01); ***H04W 72/0446*** (2013.01)

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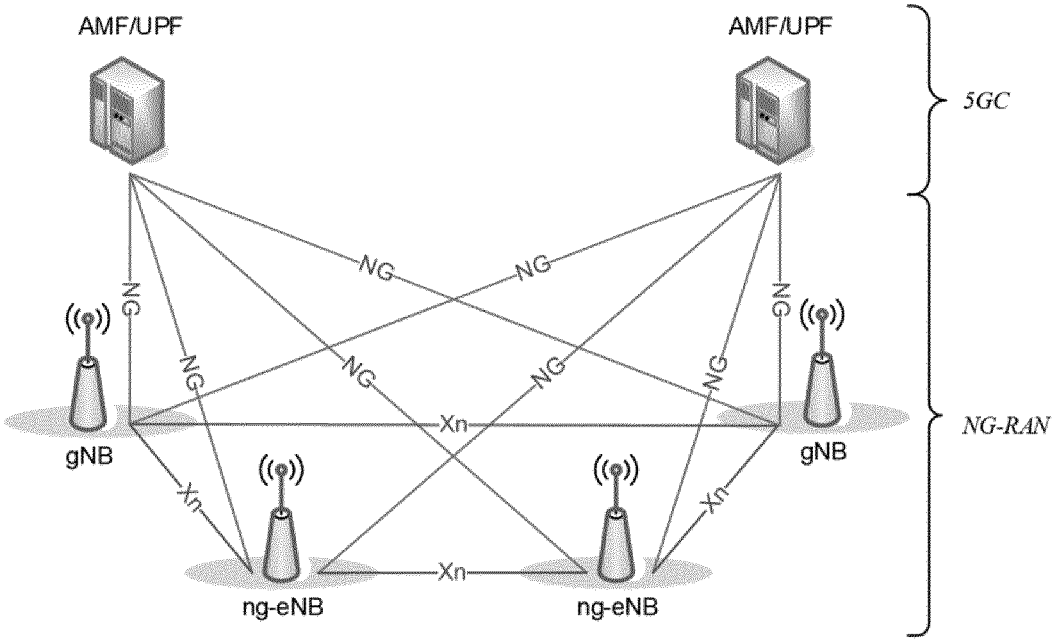
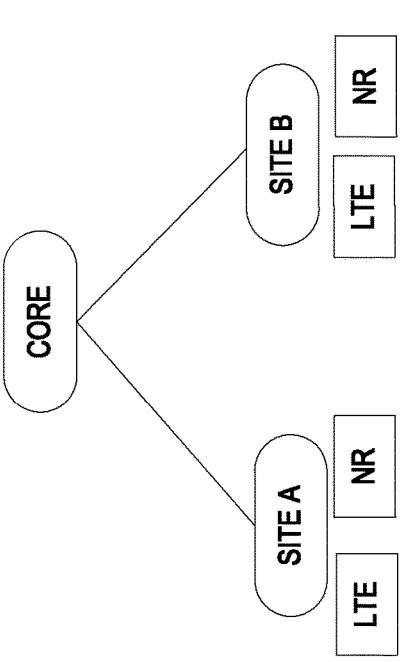
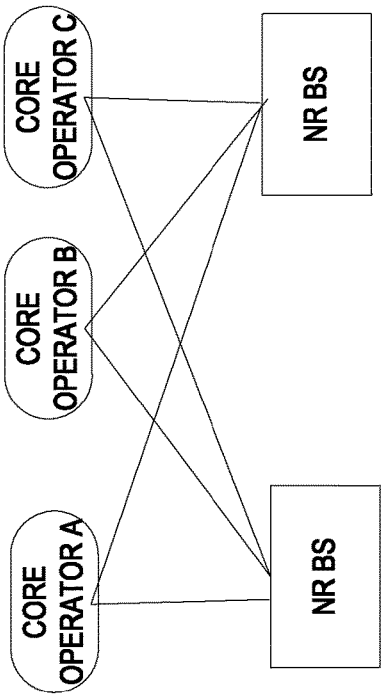

AMF/UPF
AMF/UPF
5GC
NG
NG
NG
NG
NG
NG
NG
NG
Xn
Xn
Xn
Xn
gNB
gNB
ng-eNB
ng-eNB
NG-RAN

FIG. 1



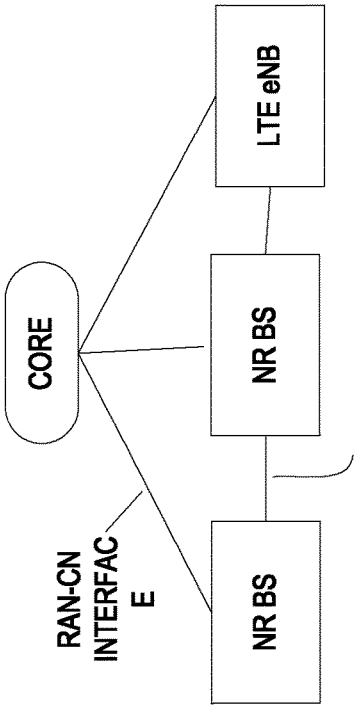
CO-SITED

FIG. 2b



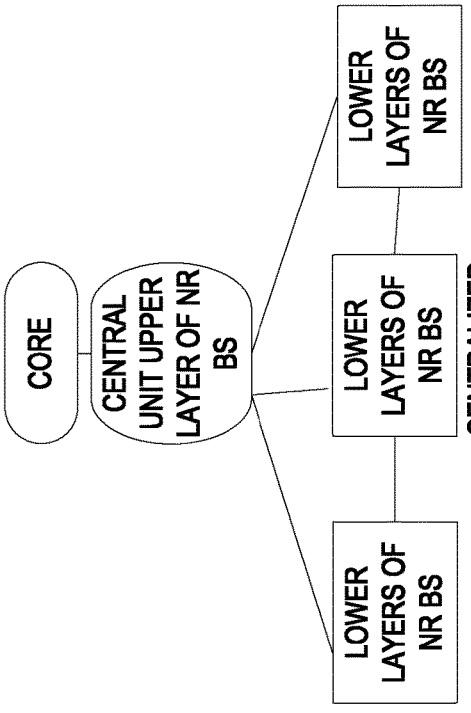
SHARED

FIG. 2d



NON-CENTRALIZED

FIG. 2a



CENTRALIZED

FIG. 2c

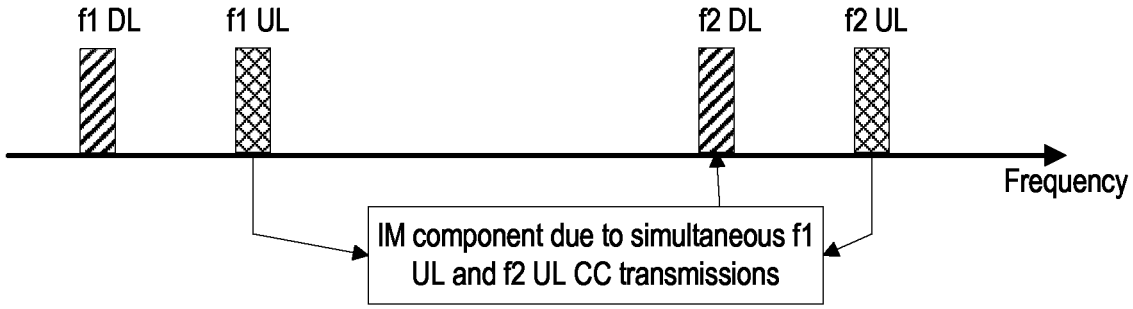

f1 DL
f1 UL
f2 DL
f2 UL
Frequency
IM component due to simultaneous f1 UL and f2 UL CC transmissions

FIG. 3

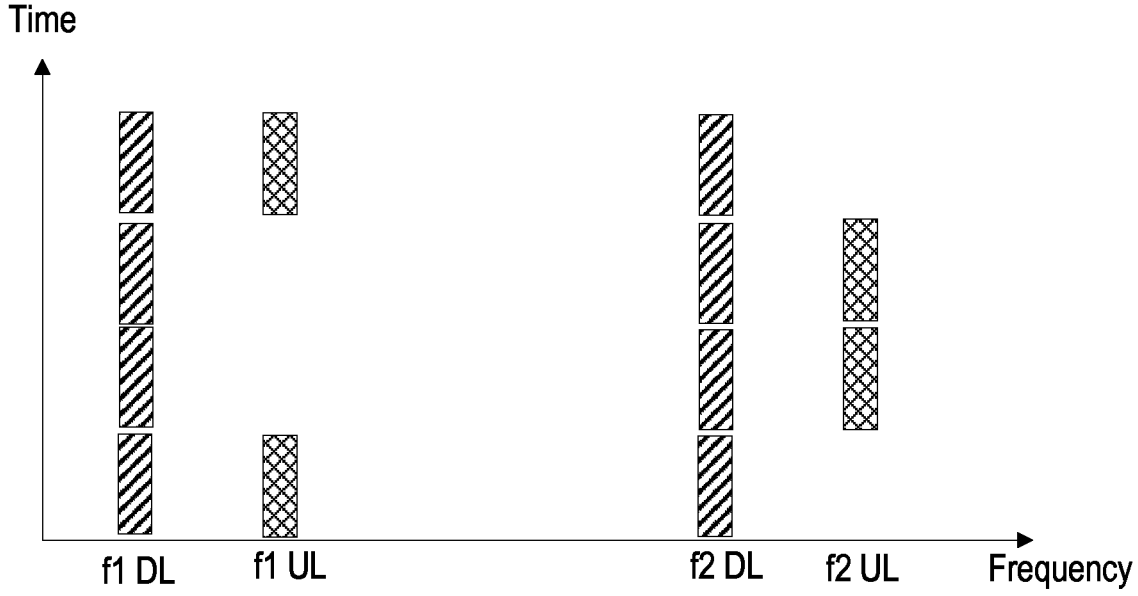

Time
f1 DL
f1 UL
f2 DL
f2 UL
Frequency

FIG. 4

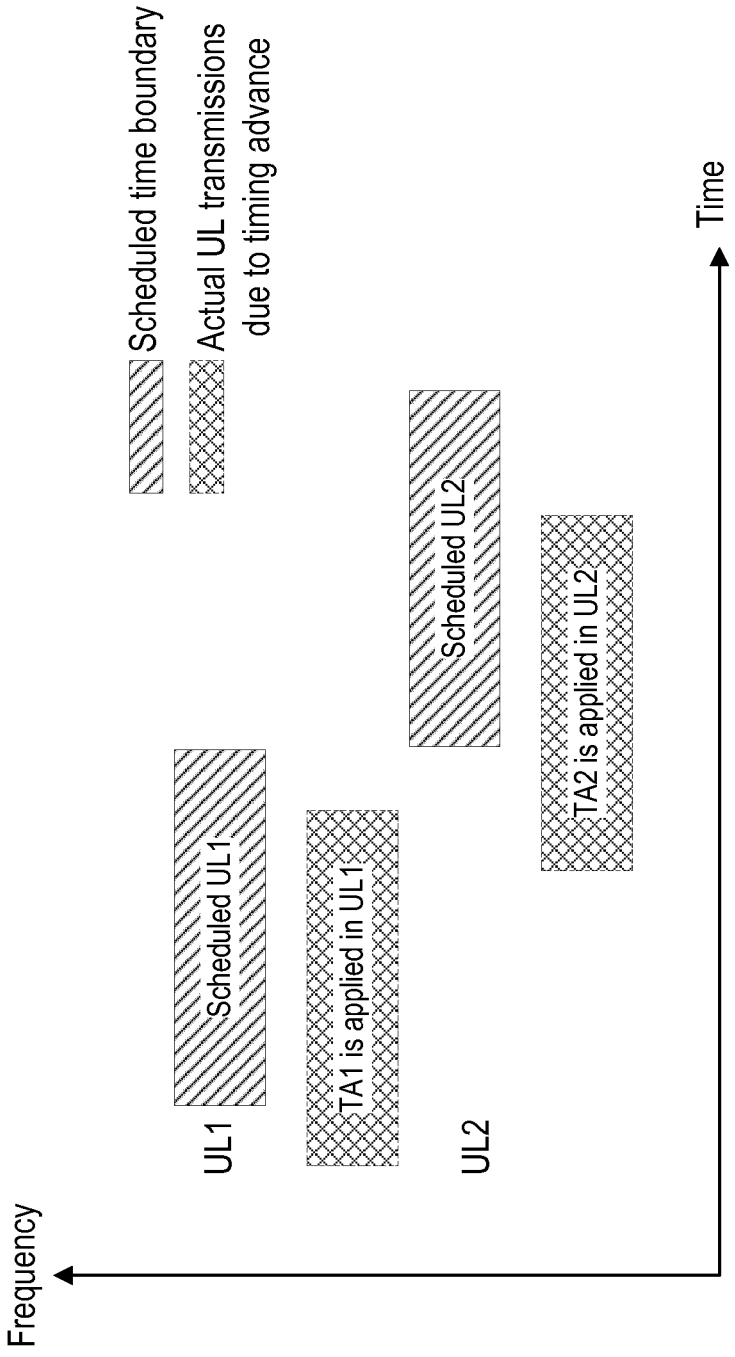

Scheduled time boundary
Actual UL transmissions due to timing advance
Scheduled UL1
TA1 is applied in UL1
Scheduled UL2
TA2 is applied in UL2
UL1
UL2
Frequency
Time

FIG. 5

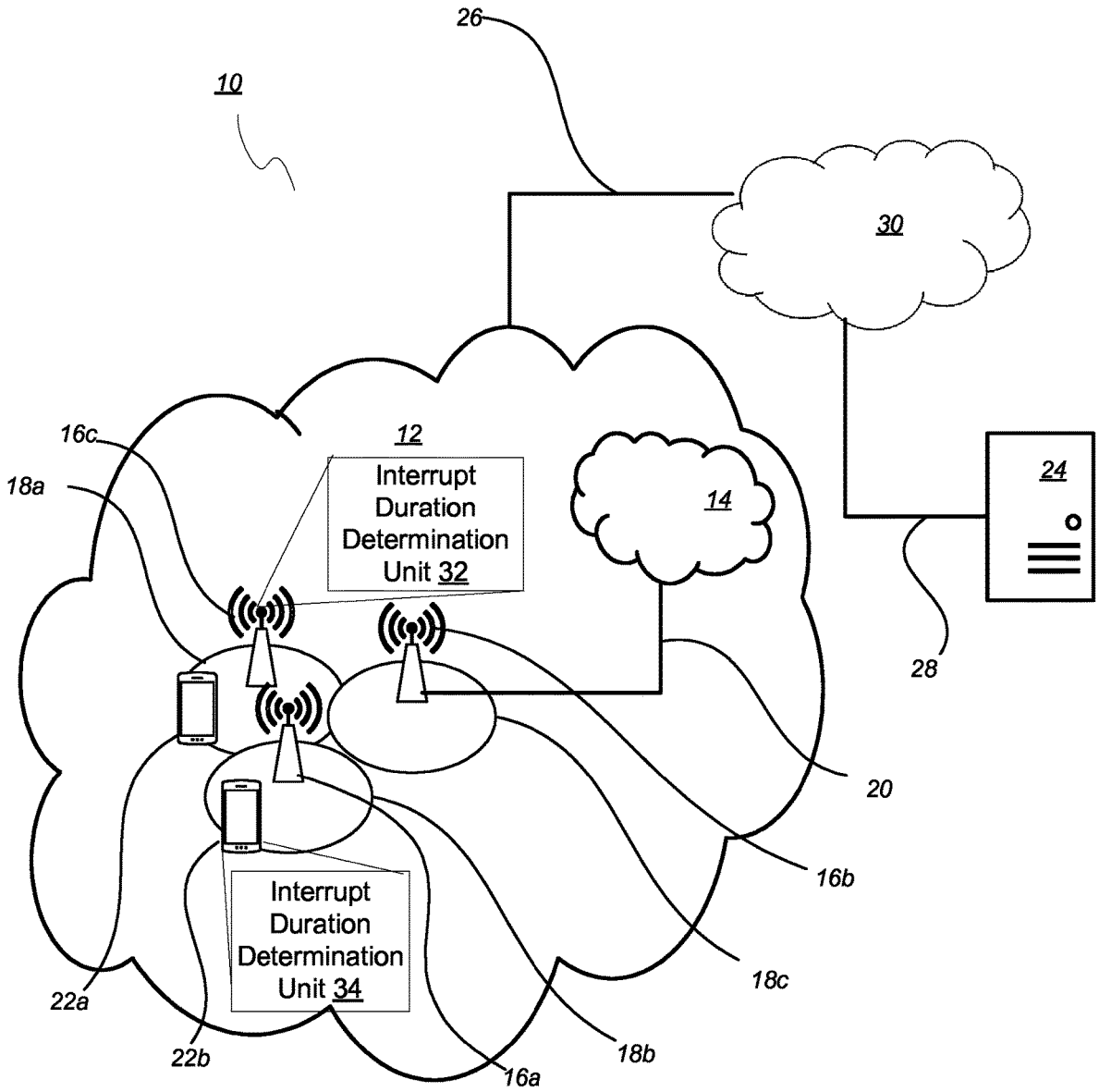

26
10
30
12
16c
18a
Interrupt Duration Determination Unit 32
14
24
28
20
16b
18c
Interrupt Duration Determination Unit 34
22a
22b
16a
18b

FIG. 6

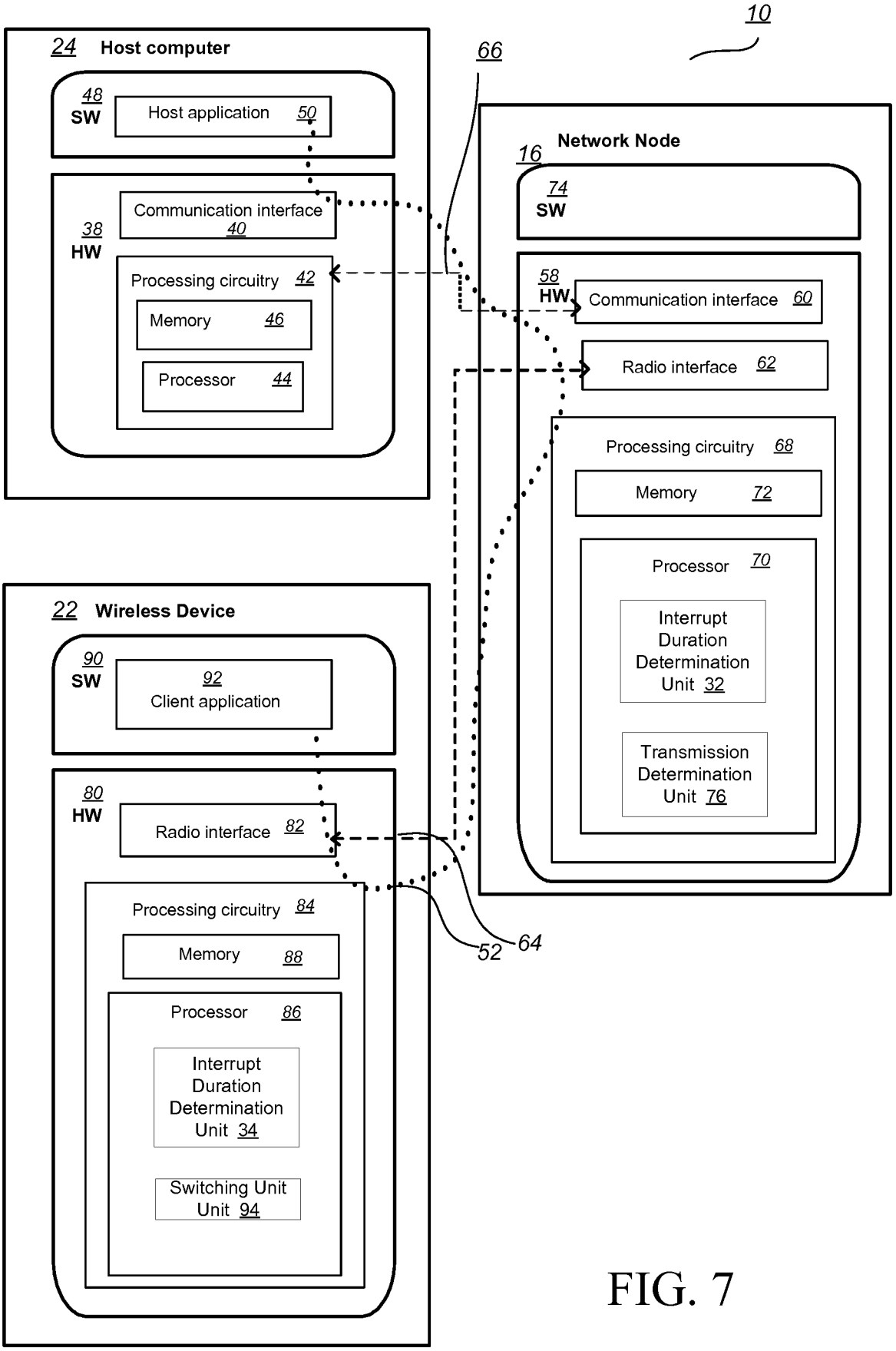

10
24 Host computer
48 SW
Host application 50
38 HW
Communication interface 40
Processing circuitry 42
Memory 46
Processor 44
66
16 Network Node
74 SW
58 HW
Communication interface 60
Radio interface 62
Processing circuitry 68
Memory 72
Processor 70
Interrupt Duration Determination Unit 32
Transmission Determination Unit 76
22 Wireless Device
90 SW
92 Client application
80 HW
Radio interface 82
Processing circuitry 84
Memory 88
Processor 86
Interrupt Duration Determination Unit 34
Switching Unit Unit 94
52
64

FIG. 7

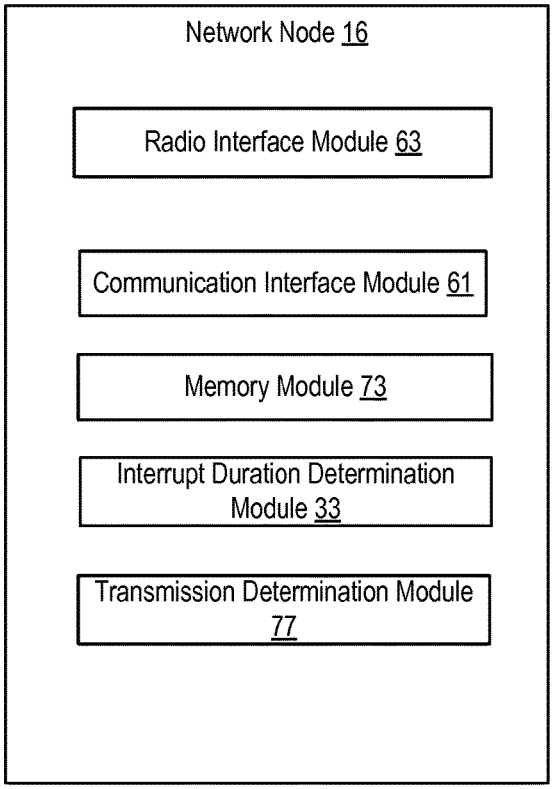


FIG. 9

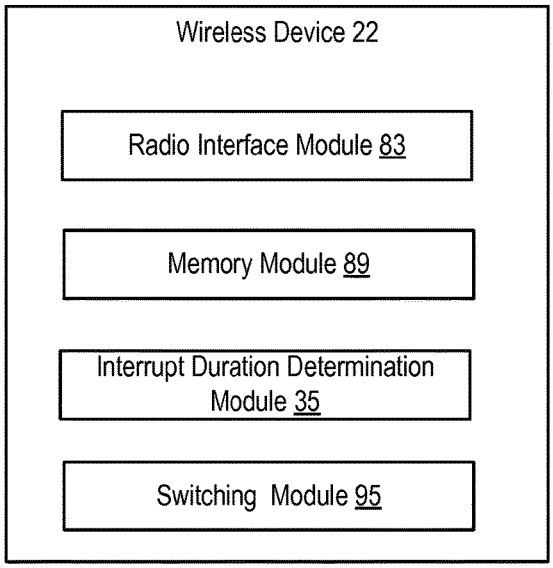


FIG. 10

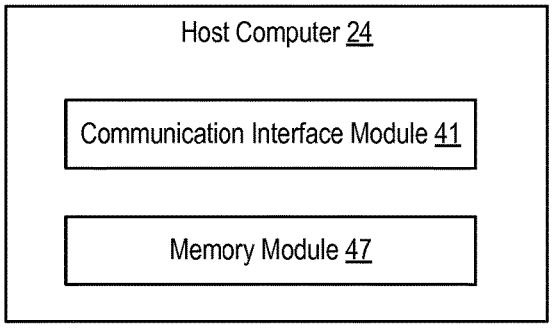


FIG. 8

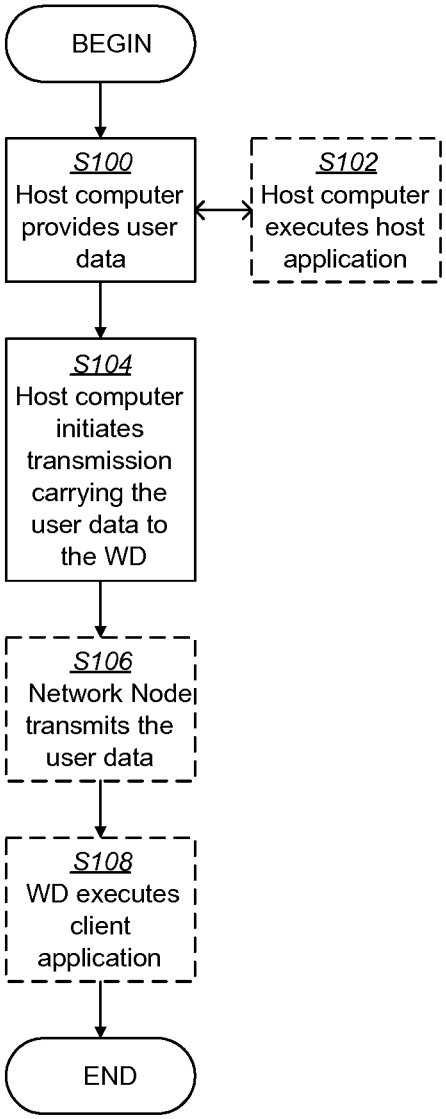

BEGIN
S100
Host computer provides user data
S102
Host computer executes host application
S104
Host computer initiates transmission carrying the user data to the WD
S106
Network Node transmits the user data
S108
WD executes client application
END

FIG. 11

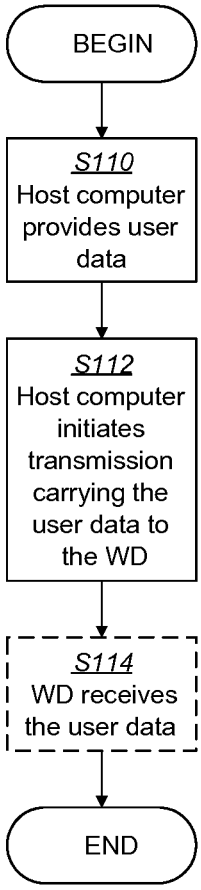

BEGIN
S110
Host computer provides user data
S112
Host computer initiates transmission carrying the user data to the WD
S114
WD receives the user data
END

FIG. 12

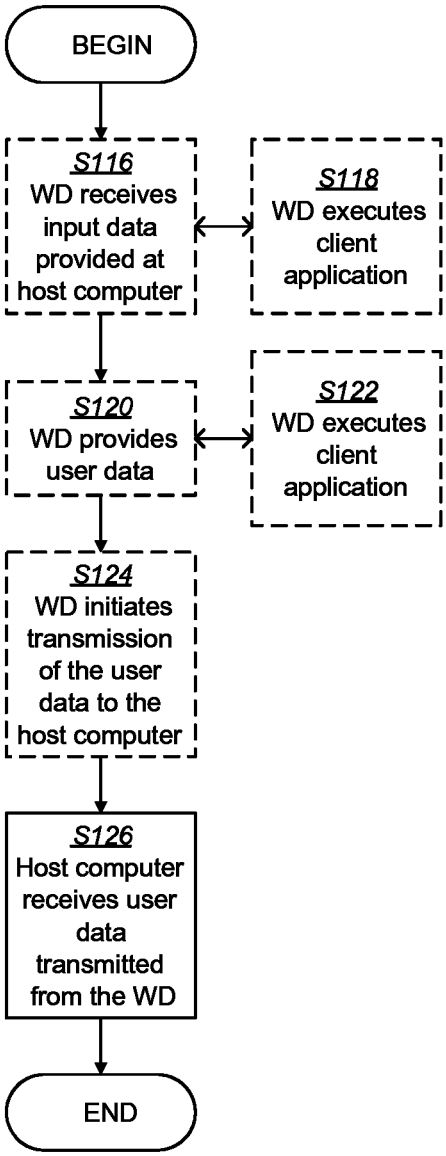

BEGIN
S116
WD receives input data provided at host computer
S118
WD executes client application
S120
WD provides user data
S122
WD executes client application
S124
WD initiates transmission of the user data to the host computer
S126
Host computer receives user data transmitted from the WD
END

FIG. 13

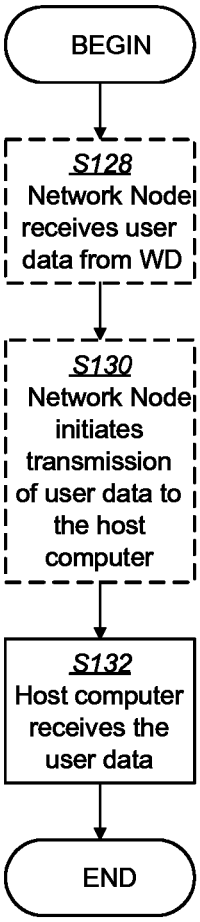

BEGIN
S128
Network Node receives user data from WD
S130
Network Node initiates transmission of user data to the host computer
S132
Host computer receives the user data
END

FIG. 14

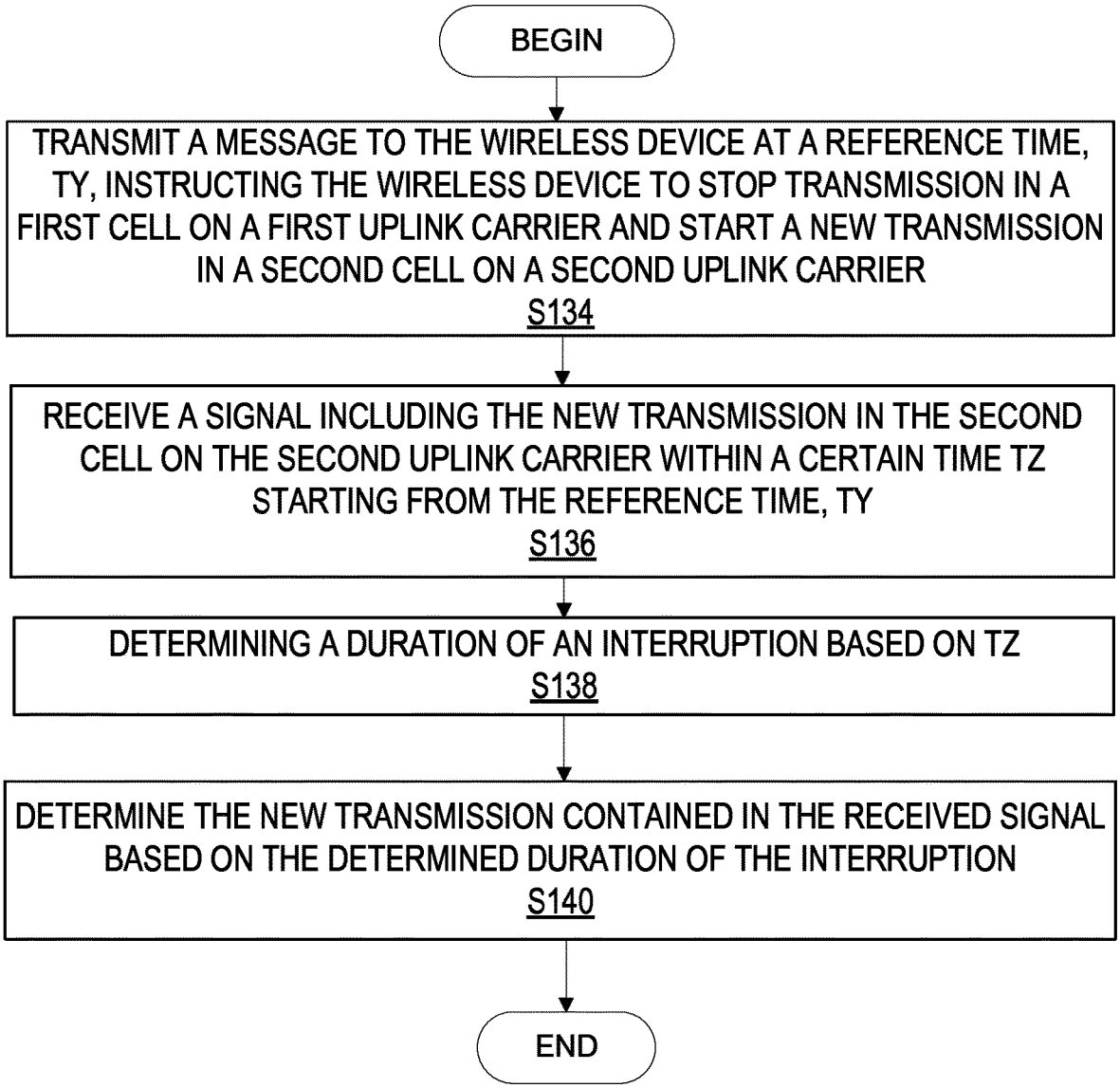

BEGIN
TRANSMIT A MESSAGE TO THE WIRELESS DEVICE AT A REFERENCE TIME, TY, INSTRUCTING THE WIRELESS DEVICE TO STOP TRANSMISSION IN A FIRST CELL ON A FIRST UPLINK CARRIER AND START A NEW TRANSMISSION IN A SECOND CELL ON A SECOND UPLINK CARRIER
S134
RECEIVE A SIGNAL INCLUDING THE NEW TRANSMISSION IN THE SECOND CELL ON THE SECOND UPLINK CARRIER WITHIN A CERTAIN TIME TZ STARTING FROM THE REFERENCE TIME, TY
S136
DETERMINING A DURATION OF AN INTERRUPTION BASED ON TZ
S138
DETERMINE THE NEW TRANSMISSION CONTAINED IN THE RECEIVED SIGNAL BASED ON THE DETERMINED DURATION OF THE INTERRUPTION
S140
END

FIG. 15

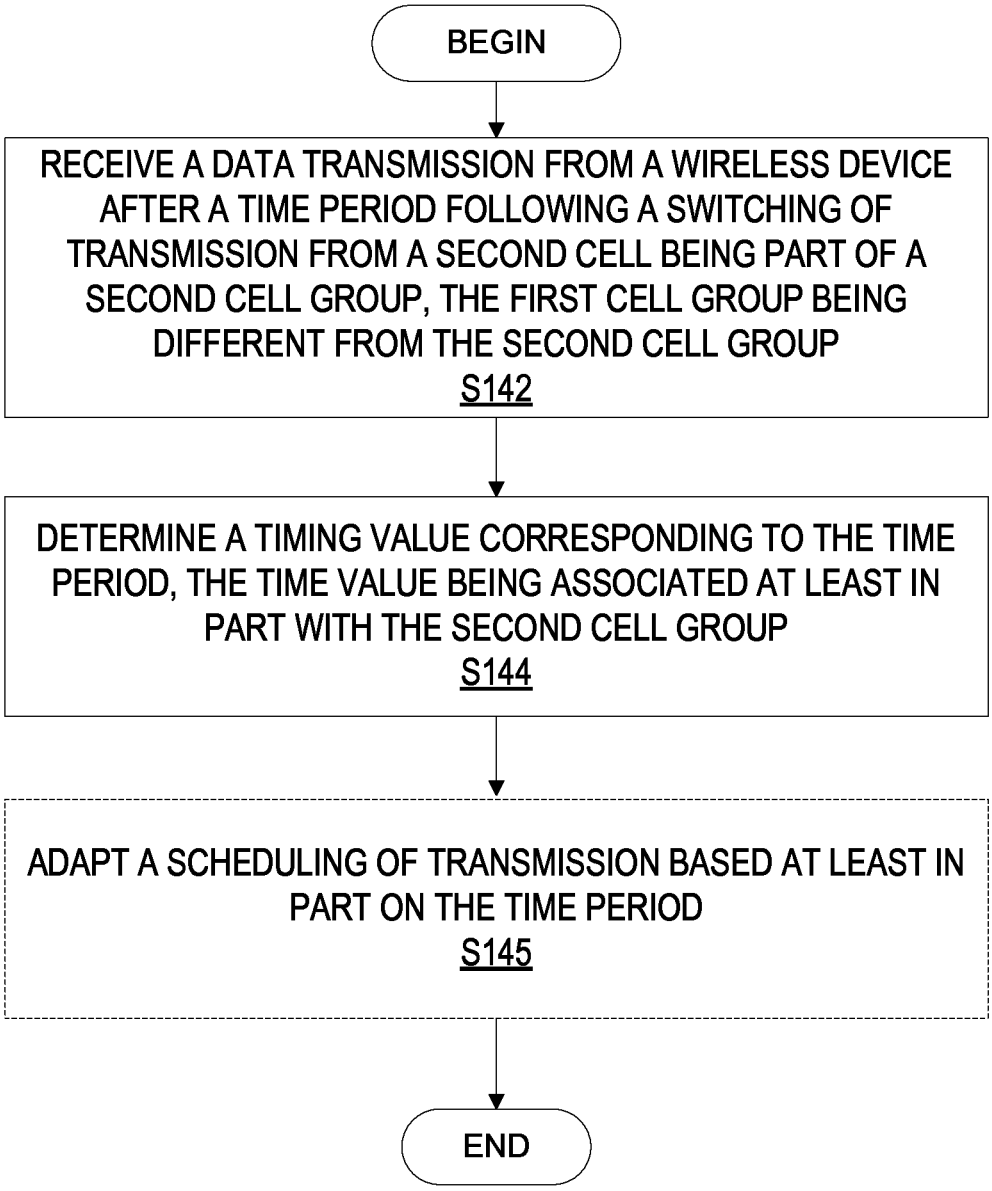

BEGIN
RECEIVE A DATA TRANSMISSION FROM A WIRELESS DEVICE AFTER A TIME PERIOD FOLLOWING A SWITCHING OF TRANSMISSION FROM A SECOND CELL BEING PART OF A SECOND CELL GROUP, THE FIRST CELL GROUP BEING DIFFERENT FROM THE SECOND CELL GROUP
S142
DETERMINE A TIMING VALUE CORRESPONDING TO THE TIME PERIOD, THE TIME VALUE BEING ASSOCIATED AT LEAST IN PART WITH THE SECOND CELL GROUP
S144
ADAPT A SCHEDULING OF TRANSMISSION BASED AT LEAST IN PART ON THE TIME PERIOD
S145
END

FIG. 16

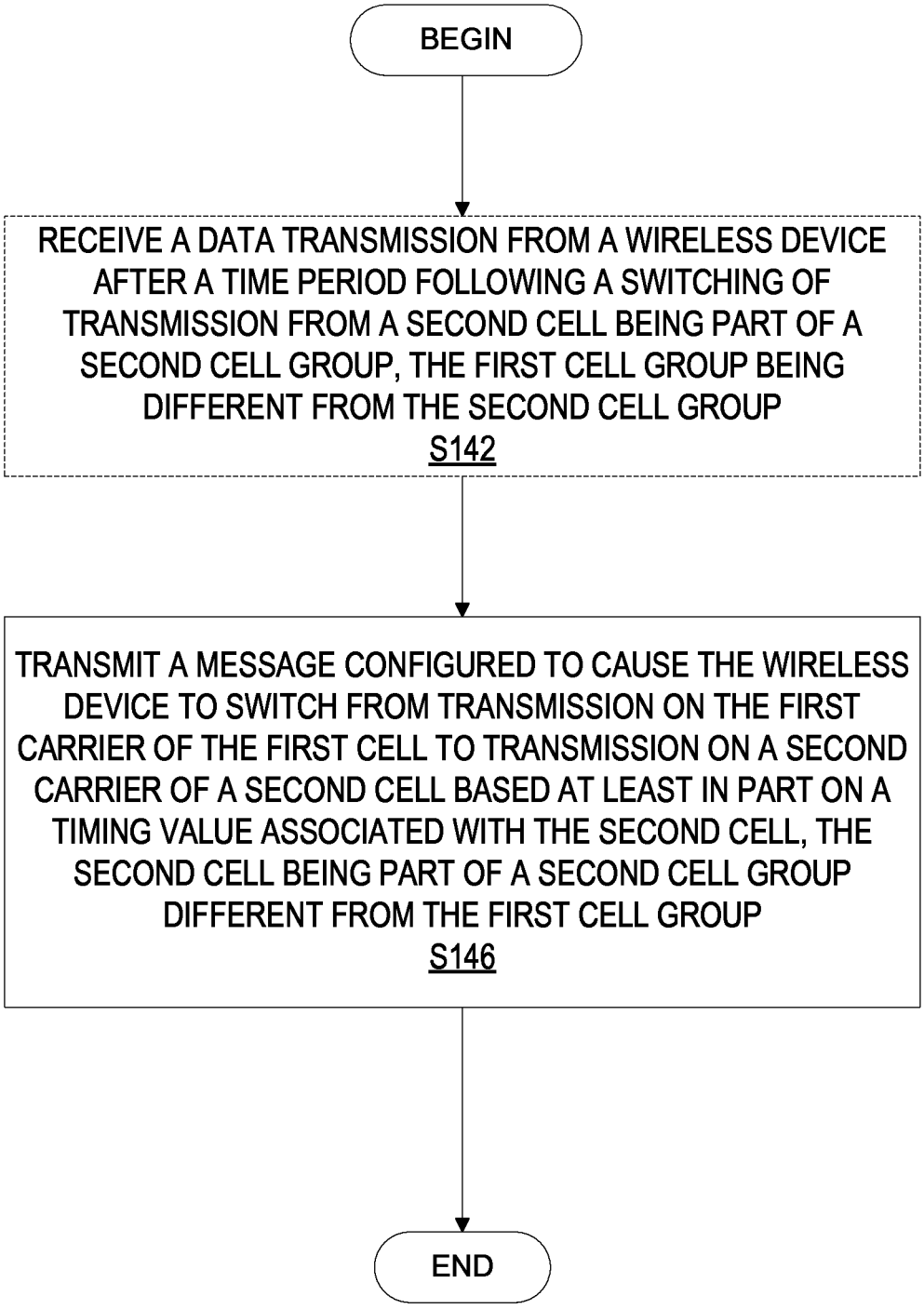

BEGIN
RECEIVE A DATA TRANSMISSION FROM A WIRELESS DEVICE AFTER A TIME PERIOD FOLLOWING A SWITCHING OF TRANSMISSION FROM A SECOND CELL BEING PART OF A SECOND CELL GROUP, THE FIRST CELL GROUP BEING DIFFERENT FROM THE SECOND CELL GROUP
S142
TRANSMIT A MESSAGE CONFIGURED TO CAUSE THE WIRELESS DEVICE TO SWITCH FROM TRANSMISSION ON THE FIRST CARRIER OF THE FIRST CELL TO TRANSMISSION ON A SECOND CARRIER OF A SECOND CELL BASED AT LEAST IN PART ON A TIMING VALUE ASSOCIATED WITH THE SECOND CELL, THE SECOND CELL BEING PART OF A SECOND CELL GROUP DIFFERENT FROM THE FIRST CELL GROUP
S146
END

FIG. 17

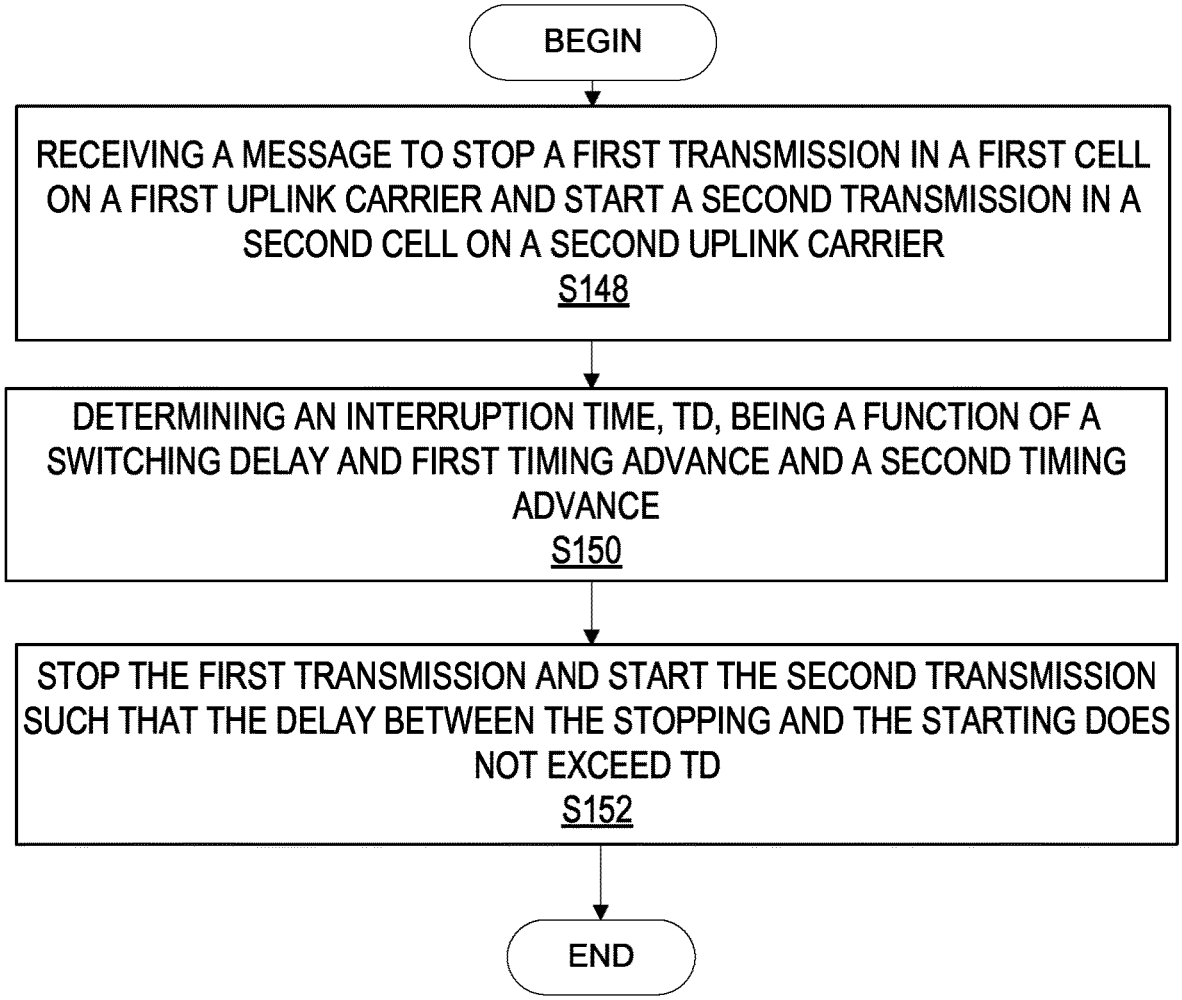

BEGIN
RECEIVING A MESSAGE TO STOP A FIRST TRANSMISSION IN A FIRST CELL ON A FIRST UPLINK CARRIER AND START A SECOND TRANSMISSION IN A SECOND CELL ON A SECOND UPLINK CARRIER
S148
DETERMINING AN INTERRUPTION TIME, TD, BEING A FUNCTION OF A SWITCHING DELAY AND FIRST TIMING ADVANCE AND A SECOND TIMING ADVANCE
S150
STOP THE FIRST TRANSMISSION AND START THE SECOND TRANSMISSION SUCH THAT THE DELAY BETWEEN THE STOPPING AND THE STARTING DOES NOT EXCEED TD
S152
END

FIG. 18

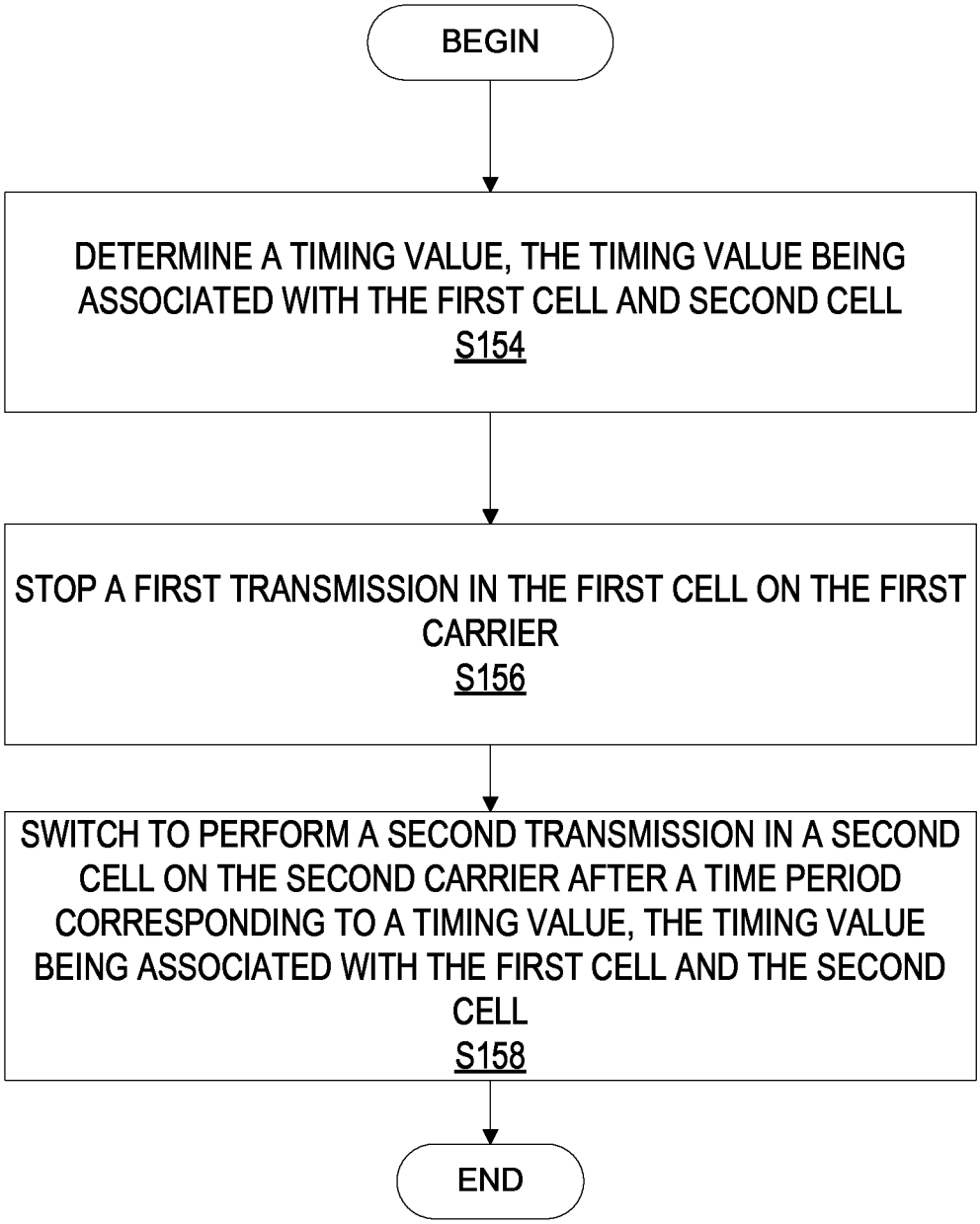

BEGIN
DETERMINE A TIMING VALUE, THE TIMING VALUE BEING ASSOCIATED WITH THE FIRST CELL AND SECOND CELL
S154
STOP A FIRST TRANSMISSION IN THE FIRST CELL ON THE FIRST CARRIER
S156
SWITCH TO PERFORM A SECOND TRANSMISSION IN A SECOND CELL ON THE SECOND CARRIER AFTER A TIME PERIOD CORRESPONDING TO A TIMING VALUE, THE TIMING VALUE BEING ASSOCIATED WITH THE FIRST CELL AND THE SECOND CELL
S158
END

FIG. 19

SWITCHING OF TRANSMISSION BETWEEN CELL GROUPS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Submission Under 35 U.S.C. § 371 for U.S. National Stage Patent Application of International Application No.: PCT/EP2018/082901, filed Nov. 28, 2018 entitled "SWITCHING OF TRANSMISSION BETWEEN CELL GROUPS," which claims priority to U.S. Provisional Application No.: 62/591,421, filed Nov. 28, 2017, entitled "METHODS AND APPARATUSES ADAPTATION OF INTERRUPTION TIME DUE TO SINGLE TRANSMIT OPERATION IN NEW RADIO," the entireties of both of which are incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to wireless communications comprising groups of cells, and in particular, to switching of transmission between cell groups.

BACKGROUND

New Radio (NR), also known as 5G or Next Generation, architecture is being discussed in Third Generation Partnership Project 3GPP and the current concept is illustrated in FIG. **1**, where eNB denotes Long Term Evolution (LTE) eNodeB, gNB and ng-eNB (or evolved eNB) denote NR base stations (BS) where one NR BS may correspond to one or more transmission/reception points, and the lines between the nodes illustrate the corresponding interfaces which are under discussion by the 3GPP. Further, FIGS. **2***a-d* illustrate deployment scenarios with NR BS which are discussed in 3GPP standards, see for example 3GPP TS 38.300 V1.2.0 (2017-11).

An architectural consideration is the dual connectivity (DC) operation involving enhanced Universal Terrestrial Radio Access (E-UTRA) and NR. In one example of Dual Connectivity (DC) operation involving E-UTRA and NR, the E-UTRA is the master. In another example of the DC operation involving E-UTRA and NR, NR is the master. The dual connectivity operation involving only NR serving cells (e.g., NR primary cell (PCell) and NR PSCells) is also envisaged.

Both standalone and non-standalone NR deployments are being discussed by the 3GPP. The standalone deployments may be single or multi-carrier (e.g., NR carrier aggregation, CA, or dual connectivity with NR PCell and NR PSCell). The non-standalone (NSA) deployment refers to a dual connectivity (DC) deployment involving E-UTRA and NR

where there is Long Term Evolution (LTE) PCell and NR PSCell (there may also be one or more LTE SCells and one or more NR SCell). LTE PCell and NR PSCell are configured in master cell group (MCG) and slave cell group (SCG) respectively. The MSG and SCG are more generally called cell groups (CG). The MCG and SCG may be configured with one or more additional serving cells, e.g., one or more LTE secondary cells (SCells) in MCG and one or more SCells in SCG.

In NR, which is based on orthogonal frequency division multiplexing (OFDM), multiple numerologies are supported for operation, e.g., transmission and/or reception of signals. The term numerology may characterize any one or more of: frame duration, subframe or transmission time interval (TTI) duration, slot duration, min-slot duration, symbol durations subcarrier spacing, number of subcarriers per physical channel (e.g., resource blocks (RB)), and number of RBs within the bandwidth.

A scaling approach (based on a scaling factor 2^N, N=1, 2, . . .) is considered for deriving subcarrier spacings for NR: 15 kHz, 30 kHz, 60 kHz, 120 KHz, etc. The numerology-specific time resource durations (e.g., slot, subframe, etc.) can then be determined in milliseconds (ms) based on the subcarrier spacing: subcarrier spacing of (2^N*15) kHz gives exactly $1/2^N$ ms.

Table 1 illustrates examples of numerology for NR in terms of carrier spacings, slot duration, symbol duration, CP length etc.

TABLE 1

Subcarrier spacing	15 kHz	30 kHz (2 × 15 kHz)	60 kHz (4 × 15 kHz)	120 kHz (8 × 15 kHz)	240 kHz (16 × 15 kHz)
Example slot duration	500 μs	250 μs	125 μs	77.5 μs	38.75 μs
OFDM symbol, duration	66.67 μs	33.33 μs	16.67 μs	8.335 μs	4.1675 μs
Cyclic prefix, duration	4.76 μs	2.38 μs	1.19 μs	0.595 μs	0.2975 μs
OFDM symbol including cyclic prefix	71.43 μs	35.71 μs	17.86 μs	8.93 μs	4.465 μs

In a recent 3GPP proposal, some LTE-NR aggregation combinations of "channels" across two bands are considered difficult to achieve, because the simultaneous uplink transmissions on these bands give rise to inter-modulation (IM) products in a downlink (DL), i.e., from base station to wireless device, band. As example of this occurrence is shown in FIG. **3**. In this case, an example of inter-band frequency division duplex (FDD)-FDD case is shown. The same also happens for tide division duplex (TDD)-TDD combinations. This means that there will be combinations of "channels" across the said two bands that are not difficult to achieve, which means that the wireless device must support dual simultaneous uplink for the band combination. The definition of "channel" is still not finalized, however is expected to be a "part" of spectrum.

For the aggregation combinations where IM products due to simultaneous multiple uplink (UL), i.e., from wireless device to base station, transmitters to DL receivers in the wireless device are caused, a test case with few test points has been proposed. The test case includes a maximum allowed DL desensitization (MSD) with respect to reference sensitivity (REFSENS) for the ULs at given power levels and the PRB allocations on the two UL carriers set so as to maximize the desensitization. The MSD will be a worst case

value based on multi-vendor input and containment margin. In practice, any problems with IM depend on the actual output power of the UL, the power balance, the allocations, the wanted signal levels and other interference. Then, the different wireless device implementations will have varying performance. In an ideal scenario, the BS will get channel state information (CSI) reports and PHR and may perhaps be able to take action for a "notorious" band combination, if the IM can be distinguished from other external interference. It is worth noting here that the same problem will happen with transmit (TX) harmonics and harmonic mixing in principle (wireless device performance will differ). IM levels up to 7th or 9th order may be considered. Then, many aggregation combinations would result.

In the table below (Table 2), examples when IMD2 or IMD3 may affect a receive (Rx) channel of the PCell based on the location of UL channels are shown.

TABLE 2

LTE Band (FDD)	NR Band (TDD)	IMD Order Falling in Rx Band
1	n77	2
3	n77	2
3	n78	2
28	n50	2
20	n28	3

Implementation of dual-UL is certainly possible at higher expense in terms of additional RF components, e.g., two TX digital front end, additional TX phase locked loop (PLL), additional TX measurement receiver, power management between two ULs (of different stacks), multiplexer filters needed after PA (duplexers replaced by multiplexers), isolation between the TX paths, etc.

One way of avoiding the IM problem is to use one single UL component carrier (CC) at any point of time as shown in FIG. **4**. In this figure, the wireless device only transmits one single UL at any point of time to avoid the IM problem. Thus, single TX transmission is ensured. The technique can be used in any radio access technologies (RAT) or any combination of RATs, e.g., this is applicable for transmission for only LTE or NR or on both LTE and NR.

In a single TX operation, when more than one UL CC is configured, and UL transmissions are switched due to a single RF TX chain, transmission collisions may occur when the UL is switched. This is shown in FIG. **5**. In this case, two UL CCs are in different timing advance groups (TAGs). We denote corresponding timing advance values as TA1 and TA2, respectively. If TA2>TA1, then the transmission of UL-CC2 needs to start before transmission of UL-CC1 stops.

A very large number of band combinations are being specified for LTE and NR dual connectivity (EN-DC) operation, see for example 3GPP TR 37.863-05-01 V0.0.1 (2017-10). Several of these band combinations may cause intermodulation (IMD) problems at the wireless device receiver, e.g., intermodulation distortion (IMD) generated by the UL of LTE in MCG and UL of NR in SCG. To avoid the IMD problem, some of these EN-DC combinations will employ only a single uplink transmission at a time. This means the wireless device will have to switch the single UL RF chain between LTE and NR UL transmissions.

SUMMARY

In existing system, wireless device behavior in terms of switching between one carrier of one cell to another carrier in another cell is not defined. For example, the wireless device behavior in terms of switching between the uplinks of LTE and NR is not defined. Without such wireless device behavior being defined, the network may not be able to efficiently schedule the wireless device. This in turn may lead to loss in wireless device UL throughput and also loss in the aggregated system throughput.

The instant disclosure advantageously solves at least a portion of at least one problem of existing systems by defining wireless device behavior related to switching between one carrier on one cell to another carrier on another cell. Some embodiments advantageously provide methods, systems, network nodes and wireless devices for switching of transmission of a wireless device from a first cell that is part of a first cell group to a second cell that is part of a second cell group based at least in part on a timing value.

According to one aspect of the disclosure, a network node is configured to provide a first cell on a first carrier and to communicate with a wireless device where the first cell is part of a first cell group is provided. The network node includes processing circuitry configured to: receive a transmission from a wireless device after a time period following a switching of a transmission from a second cell being part of a second cell group, the first cell group being different from the second cell group; and determine a timing value corresponding to the time period, the time value being associated at least in part with the second cell group. Various examples are provided in relation to this first aspect for determining the timing value and adapting the scheduling as a result.

According to another aspect of the disclosure, a method performed by a network node configured to provide a first cell on a first carrier and to communicate with a wireless device where the first cell being part of a first cell group is provided. A transmission is received from a wireless device after a time period following a switching of a transmission from a second cell being part of a second cell group, the first cell group being different from the second cell group. A timing value corresponding to the time period is determined where the time value being associated at least in part with the second cell group. Various examples are provided in relation to this second aspect for determining the timing value and adapting the scheduling as a result.

In one or more embodiments, the time period is determined by the network node in response to a message sent to the wireless device to instruct the wireless device to stop transmission in the second cell and start a new transmission in the first cell. In one or more embodiments, the first cell and the second cell are provided by a first network node and a second network node, respectively, and the wireless device is instructed to start the new transmission in the first cell at a reference time, Ty, by the second network node and the determining of the time period is based on the first network node receiving an indication of the reference time, Ty from the second network node.

In one or more embodiments, the timing value is based at least in part on a timing advance of the second cell group and a timing advance of the first cell group. In one or more embodiments, the timing value is based at least in part on a radio frequency, RF, switching time of the wireless device. In one or more embodiments, the timing value is a function of at least one of a radio frequency, RF, switching time of the wireless device, a timing advance of the first cell group and a timing advance of the second cell group. In one or more embodiments, the timing value is based at least in part on at least one of a sum, difference, maximum and product of at least two of: the RF switching time of the wireless device;

the timing advance of the first cell group; the timing advance of the second cell group; and the function of at least one of the RF switching time of the wireless device, the timing advance of the first cell group and the timing advance of the second cell group

In one or more embodiments, the timing value is further based at least in part on an error due to one of reception and transmission at the wireless device. In one or more embodiments, the timing value is further based at least in part on an autonomous timing adjustment delay of the wireless device. In one or more embodiments, the first cell is associated with a first radio access technology, RAT, and the second cell is associated with a second RAT different from the first RAT. In one or more embodiments, the first cell and the second cell are provided by the network node. In one or more embodiments, the processing circuitry is further configured to adapt a scheduling of transmissions based at least in part on the time period.

According to another aspect of the disclosure, a network node configured to provide a first cell on a first carrier and to communicate with a wireless device where the first cell being part of a first cell group is provided. The network node includes processing circuitry configured to transmit a message configured to cause the wireless device to switch from transmission on the first carrier of the first cell to transmission on a second carrier of a second cell based at least in part on a timing value associated with the second cell, the second cell being part of a second cell group different from the first cell group.

According to another aspect of the disclosure, a method performed by a network node configured to provide a first cell on a first carrier and to communicate with a wireless device where the first cell being part of a first cell group is provided. A message configured to cause the wireless device (**22**) to switch from transmission on the first carrier of the first cell to transmission on a second carrier of a second cell based at least in part on a timing value associated with the second cell is transmitted. The second cell is part of a second cell group different from the first cell group.

In one or more embodiments, the message is one of a radio resource control message, medium access control message and layer 1 message. In one or more embodiments, the processing circuitry is further configured to determine a reference time, Ty, at which the wireless device is to start transmission on the second carrier of the second cell, the reference time, Ty, is indicated in the message. In one or more embodiments, the timing value is based at least in part on a timing advance of the second cell group and a timing advance of the first cell group. In one or more embodiments, the timing value is based at least in part on a radio frequency, RF, switching time of the wireless device.

In one or more embodiments, the timing value corresponds to a delay in uplink transmission, at least a portion of the delay in the uplink transmission being applied to at least one of an uplink transmission in the first cell and an uplink transmission in the second cell. In one or more embodiments, the timing value is a function of at least one of a radio frequency, RF, switching time of the wireless device, a timing advance of the first cell group and a timing advance of the second cell group. In one or more embodiments, the timing value is based at least in part on at least one of a sum, difference, maximum and product of at least two of: the RF switching time of the wireless device; the timing advance of the first cell group; the timing advance of the second cell group; and the function of at least one of the RF switching time of the wireless device, the timing advance of the first cell group and the timing advance of the second cell group. In one or more embodiments, the timing value is further based at least in part on an error due to one of reception and transmission at the wireless device.

In one or more embodiments, the timing value is further based at least in part on an autonomous timing adjustment delay of the wireless device. In one or more embodiments, the first cell and the second cell are provided by the network node. In one or more embodiments, the first cell is associated with a first radio access technology, RAT, and the second cell is associated with a second RAT different from the first RAT.

According to another aspect of the disclosure, a wireless device configured to communicate on a first carrier with a first cell that is part of a first cell group and on a second carrier with a second cell that is part of a second cell group different from the first cell group is provided. The wireless device includes processing circuitry configured to: determine a timing value, the timing value being associated with the first cell and second cell; stop a first transmission in the first cell on the first carrier; and switch to perform a second transmission in a second cell on the second carrier after a time period corresponding to the timing value.

According to another aspect of the disclosure, a method performed by a wireless device configured to communicate on a first carrier with a first cell that is part of a first cell group and on a second carrier with a second cell that is part of a second cell group different from the first cell group is provided. A timing value is determined where the timing value being associated with the first cell and second cell. A first transmission in the first cell on the first carrier is stopped. A second transmission in a second cell on the second carrier after a time period corresponding to the timing value is performed.

In one or more embodiments, the processing circuitry is further configured to receive a message from the first cell where the stopping of the first transmission in the first cell and the performing of the second transmission in the second cell being in response to the message. In one or more embodiments, the message includes an indication to apply at least a portion of a delay in transmission to at least one of an uplink transmission in the first cell and an uplink transmission in the second cell, the delay corresponding to the timing value. In one or more embodiments, the processing circuitry is further configured to determine whether a predefined rule is met, the stopping of the first transmission in the first cell and the performing of the second transmission in the second cell being in response to the predefined rule being met.

In one or more embodiments, the predefined rule is based on one of a numerology of a signal and predefined time period. In one or more embodiments, the message is one of a radio resource control message, medium access control message and layer 1 message. In one or more embodiments, the timing value is based at least in part on a timing advance of the second cell group and a timing advance of the first cell group. In one or more embodiments, the timing value is based at least in part on a radio frequency, RF, switching time of the wireless device. In one or more embodiments, the timing value is a function of at least one of a radio frequency, RF, switching time of the wireless device, a timing advance of the first cell group and a timing advance of the second cell group.

In one or more embodiments, the timing value is based at least in part on at least one of a sum, difference, maximum and product of at least two of: the RF switching time of the wireless device; the timing advance of the first cell group; the timing advance of the second cell group; and the function of at least one of the RF switching time of the wireless

device, the timing advance of the first cell group and the timing advance of the second cell group. In one or more embodiments, the timing value is further based at least in part on an error due to one or reception and transmission at the wireless device. In one or more embodiments, the timing value is further based at least in part on an autonomous timing adjustment delay of the wireless device.

In one or more embodiments, the timing value is based on a timing advance of the second cell group and a timing advance of the first cell group. In one or more embodiments, the first cell and the second cell are provided by a network node. In one or more embodiments, the first cell is associated with a first radio access technology, RAT, and the second cell is associated with a second RAT different from the first RAT.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present embodiments, and the attendant advantages and features thereof, will be more readily understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

FIG. **1** is a block diagram of a New Radio (NR) wireless communication system;

FIGS. **2***a-d* illustrate deployment scenarios with NR base stations;

FIG. **3** illustrates intermodulation (IM) products in a downlink band;

FIG. **4** illustrates avoidance of IM using a single uplink component carrier;

FIG. **5** illustrates a possibility of collisions when uplink transmissions are switched;

FIG. **6** is a schematic diagram of an exemplary network architecture illustrating a communication system connected via an intermediate network to a host computer according to the principles in the present disclosure;

FIG. **7** is a block diagram of a host computer communicating via a network node with a wireless device over an at least partially wireless connection according to some embodiments of the present disclosure;

FIG. **8** is a block diagram of an alternative embodiment of a host computer according to some embodiments of the present disclosure;

FIG. **9** is a block diagram of an alternative embodiment of a network node according to some embodiments of the present disclosure;

FIG. **10** is a block diagram of an alternative embodiment of a wireless device according to some embodiments of the present disclosure;

FIG. **11** is a flowchart illustrating exemplary methods implemented in a communication system including a host computer, a network node and a wireless device for executing a client application at a wireless device according to some embodiments of the present disclosure;

FIG. **12** is a flowchart illustrating exemplary methods implemented in a communication system including a host computer, a network node and a wireless device for receiving user data at a wireless device according to some embodiments of the present disclosure;

FIG. **13** is a flowchart illustrating exemplary methods implemented in a communication system including a host computer, a network node and a wireless device for receiving user data from the wireless device at a host computer according to some embodiments of the present disclosure

FIG. **14** is a flowchart illustrating exemplary methods implemented in a communication system including a host computer, a network node and a wireless device for receiving user data at a host computer according to some embodiments of the present disclosure;

FIG. **15** is a flowchart of an exemplary process in a network node configured to communicate with a wireless device according to some embodiments of the present disclosure;

FIG. **16** is a flowchart of another exemplary process in a network node according to some embodiments of the present disclosure;

FIG. **17** is a flowchart of yet another exemplary process in a network node according to some embodiments of the present disclosure;

FIG. **18** is a flowchart of an exemplary process in a wireless device configured to communicate with a network node according to some embodiments of the present disclosure; and

FIG. **19** is a flowchart of an exemplary process in a wireless device according to some embodiments of the present disclosure.

DETAILED DESCRIPTION

Some embodiments advantageously provide methods, systems, and apparatuses for adaptation of interruption time due to single transmit operation.

For example a wireless device may be configured for multi-connectivity operation (e.g., LTE and NR Dual connectivity (EN-DC)) and switches between uplink transmission in a first cell (cell1) belonging to a first timing advance group (TAG) (TAG1) (e.g., LTE TAG) and uplink transmission in a second cell (cell2) belonging to a second TAG (TAG2) (e.g., NR TAG) within a certain time delay (Td); where Td is a function of at least RF tuning time (Tr), a first TA advance (TA1) is applied by the wireless device for transmission in TAG1 and a second TA advance (TA2) is applied by the wireless device for transmission in TAG2. The value of Td may further include time to account for implementation margin (Tm) and time (Ta) for autonomous adjustment of the wireless device uplink timing in cell1 and/or cell2. The time delay, Td, corresponds to a total interruption time during which signals transmitted between the wireless device and a first network node (NW1) (e.g., eNB) and/or signals transmitted between the wireless device and a second network node (NW2) (e.g., gNB) are interrupted.

In a second example the wireless device may be configured with EN-DC and may determine whether the time delay, Td, occurs during uplink transmission of signals in TAG1 and/or during uplink transmission of signals in TAG2. The determination is based on one or more rules, which can be pre-defined and/or the determination is based on a configuration message received from the network node (e.g., from NW1 and/or NW2 or from another network node). The one or more rules can be based on: a type of signal transmitted in cell1 and/or in cell2, numerology of signals transmitted to cell1 and/or in cell2, etc.

In a third example a network node (NW) determines the total interruption time (Td), which is caused by the UE, when the wireless device is configured for multi-connectivity operation and switches between uplink transmission in cell1 of TAG1 and uplink transmission in cell2 of TAG2. The network node may adapt scheduling of signals in cell1 and/or in cell2 based on the determined value of Td.

Some advantages of some of the embodiments described further herein include:

- wireless device behavior in single TX transmission is well defined and thus provides known and consistent interoperability;
- The network node is able to schedule the wireless device with optimized resources which provides more optimized resource allocation performance; and/or
- The network node has better control over the wireless device operation in multicarrier operation since the interruption can be controlled, e.g., of either occurs in PCell or in PSCell or partially in both serving cells.

Before describing in further detail exemplary embodiments, it is noted that the embodiments reside primarily in combinations of apparatus components and processing steps related to adaptation of interruption time due to single transmit operation. Accordingly, components have been represented where appropriate by conventional symbols in the drawings, showing only those specific details that are pertinent to understanding the embodiments so as not to obscure the disclosure with details that will be readily apparent to those of ordinary skill in the art having the benefit of the description herein. Like numbers refer to like elements throughout the description.

As used herein, relational terms, such as "first" and "second," "top" and "bottom," and the like, may be used solely to distinguish one entity or element from another entity or element without necessarily requiring or implying any physical or logical relationship or order between such entities or elements. The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the concepts described herein. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises," "comprising," "includes" and/or "including" when used herein, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

In embodiments described herein, the joining term, "in communication with" and the like, may be used to indicate electrical or data communication, which may be accomplished by physical contact, induction, electromagnetic radiation, radio signaling, infrared signaling or optical signaling, for example. One having ordinary skill in the art will appreciate that multiple components may interoperate and modifications and variations are possible of achieving the electrical and data communication.

In some embodiments described herein, the term "coupled," "connected," and the like, may be used herein to indicate a connection, although not necessarily directly, and may include wired and/or wireless connections.

The term "network node" used herein can be any kind of network node comprised in a radio network which may further comprise any of base station (BS), radio base station, base transceiver station (BTS), base station controller (BSC), radio network controller (RNC), g Node B (gNB), evolved Node B (eNB or eNodeB), Node B, multi-standard radio (MSR) radio node such as MSR BS, multi-cell/multicast coordination entity (MCE), relay node, donor node controlling relay, radio access point (AP), transmission points, transmission nodes, Remote Radio Unit (RRU) Remote Radio Head (RRH), a core network node (e.g., mobile management entity (MME), self-organizing network (SON) node, a coordinating node, positioning node, MDT node, etc.), an external node (e.g., 3rd party node, a node external to the current network), nodes in distributed antenna system (DAS), a spectrum access system (SAS) node, an element management system (EMS), etc. The network node may also comprise test equipment. The term "radio node" used herein may be used to also denote a wireless device such as a user equipment (UE) or a radio network node.

In some embodiments, the non-limiting terms wireless device or a user equipment (UE) are used interchangeably. The wireless device herein can be any type of wireless device capable of communicating with a network node or another wireless device over radio signals, such as wireless device. The wireless device may also be a radio communication device, target device, device to device (D2D) wireless device, machine type wireless device or wireless device capable of machine to machine communication (M2M), low-cost and/or low-complexity wireless device, a sensor equipped with wireless device, Tablet, mobile terminals, smart phone, laptop embedded equipped (LEE), laptop mounted equipment (LME), USB dongles, Customer Premises Equipment (CPE), an Internet of Things (IoT) device, or a Narrowband IoT (NB-IOT) device etc.

Also, in some embodiments the generic term "radio network node" is used. It can be any kind of a radio network node which may comprise any of base station, radio base station, base transceiver station, base station controller, network controller, RNC, evolved Node B (eNB), Node B, gNB, Multi-cell/multicast Coordination Entity (MCE), relay node, access point, radio access point, Remote Radio Unit (RRU) Remote Radio Head (RRH).

A component carrier (CC) also interchangeably called a carrier, primary CC (PCC) or secondary CC (SCC) is configured at the wireless device by the network node using higher layer signaling e.g. by sending RRC configuration message to the UE. The configured CC is used by the network node for serving the wireless device **22** on the serving cell (e.g. on PCell, PSCell, SCell, etc.) of the configured CC. The configured CC is also used by the wireless device **22** for performing one or more radio measurements (e.g. RSRP, RSRQ, etc.) on the cells operating on the CC e.g. PCell, SCell or PSCell and neighboring cells. In some embodiments the wireless device **22** may be configured with PCell and PSCell or with PCell, PSCell and one or more SCells such as in carrier aggregation or dual connectivity. The configured cells are wireless device **22** specific and are also called as serving cells of the UE.

The term time resource used herein may correspond to any type of physical resource or radio resource expressed in terms of length of time. Examples of time resources are: symbol, time slot, subframe, radio frame, TTI, short or shortened TTI, interleaving time, special subframe, UpPTS, etc.

In this disclosure, switching between two UL cells are mentioned, however any switching between more than two cells are also covered under the embodiments, unless otherwise mentioned.

Note that although terminology from one particular wireless system, such as, for example, 3GPP LTE, may be used in this disclosure, this should not be seen as limiting the scope of the disclosure to only the aforementioned system. Other wireless systems, including without limitation Wide Band Code Division Multiple Access (WCDMA), Worldwide Interoperability for Microwave Access (WiMax), Ultra Mobile Broadband (UMB) and Global System for Mobile Communications (GSM), may also benefit from exploiting the ideas covered within this disclosure.

Note further, that functions described herein as being performed by a wireless device or a network node may be distributed over a plurality of wireless devices and/or network nodes. In other words, it is contemplated that the functions of the network node and wireless device described herein are not limited to performance by a single physical device and, in fact, can be distributed among several physical devices.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. It will be further understood that terms used herein should be interpreted as having a meaning that is consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

Embodiments provide for adaptation of interruption time due to single transmit operation. For example, in some embodiments, a network node may transmit a message to the wireless device at a reference time, Ty, instructing the wireless device to stop transmission in a first cell on a first uplink carrier and start a new transmission in a second cell on a second uplink carrier. The network node may then receive a signal including the new transmission in the second cell on the second uplink carrier within a certain time Tz starting from the reference time, Ty. The network node determines a duration of an interruption based on Tz and determines the new transmission contained in the received signal based on the determined duration of the interruption. In one or more embodiments, one or more of the following may be an example of a timing value: Tz and a duration of an interruption. As another example, in some embodiments, a wireless device receives from the network node a message instructing the wireless device **22** to stop a first transmission in a first cell on a first uplink carrier and start a second transmission in a second cell on a second uplink carrier. The wireless device determines an interruption time, Td, being a function of a switching delay and first timing advance and a second timing advance. The wireless device is configured to stop the first transmission and start the second transmission such that the delay between the stopping and the starting does not exceed Td. In one or more embodiments, the interruption time is an example of a timing value.

Returning to the drawing figures, in which like elements are referred to by like reference numerals, there is shown in FIG. **6** a schematic diagram of a communication system, according to an embodiment, including a communication system **10**, such as a 3GPP-type cellular network, which comprises an access network **12**, such as a radio access network, and a core network **14**. The access network **12** comprises a plurality of network nodes **16***a*, **16***b*, **16***c* (referred to collectively as network nodes **16**), such as NBs, eNBs, gNBs or other types of wireless access points, each defining a corresponding coverage area **18***a*, **18***b*, **18***c* (referred to collectively as coverage areas **18**). Each network node **16***a*, **16***b*, **16***c* is connectable to the core network **14** over a wired or wireless connection **20**. A first wireless device **22***a* located in coverage area **18***a* is configured to wirelessly connect to, or be paged by, the corresponding network node **16***c*. A second wireless device **22***b* in coverage area **18***b* is wirelessly connectable to the corresponding network node **16***a*. While a plurality of wireless devices **22***a*, **22***b* (collectively referred to as wireless devices **22**) are illustrated in this example, the disclosed embodiments are equally applicable to a situation where a sole wireless device **22** is in the coverage area or where a sole is connecting to the corresponding network node **16**. Note that although only two wireless devices **22** and three network nodes **16** are shown for convenience, the communication system may include many more wireless devices **22** and network nodes **16**.

The communication system **10** may itself be connected to a host computer **24**, which may be embodied in the hardware and/or software of a standalone server, a cloud-implemented server, a distributed server or as processing resources in a server farm. The host computer **24** may be under the ownership or control of a service provider, or may be operated by the service provider or on behalf of the service provider. The connections **26**, **28** between the communication system **10** and the host computer **24** may extend directly from the core network **14** to the host computer **24** or may extend via an optional intermediate network **30**. The intermediate network **30** may be one of, or a combination of more than one of, a public, private or hosted network. The intermediate network **30**, if any, may be a backbone network or the Internet. In some embodiments, the intermediate network **30** may comprise two or more sub-networks (not shown).

The communication system of FIG. **6** as a whole enables connectivity between one of the connected wireless devices **22***a*, **22***b* and the host computer **24**. The connectivity may be described as an over-the-top (OTT) connection. The host computer **24** and the connected wireless devices **22***a*, **22***b* are configured to communicate data and/or signaling via the OTT connection, using the access network **12**, the core network **14**, any intermediate network **30** and possible further infrastructure (not shown) as intermediaries. The OTT connection may be transparent in the sense that at least some of the participating communication devices through which the OTT connection passes are unaware of routing of uplink and downlink communications. For example, a network node **16** may not or need not be informed about the past routing of an incoming downlink communication with data originating from a host computer **24** to be forwarded (e.g., handed over) to a connected wireless device **22***a*. Similarly, the network node **16** need not be aware of the future routing of an outgoing uplink communication originating from the wireless device **22***a* towards the host computer **24**.

A network node **16** is configured to include an interrupt duration determination unit **32** which is configured to perform one or more functions described herein such as determining a duration of an interruption between stopping a first transmission and starting a second transmission. A wireless device **22** is configured to include an interrupt duration determination unit **34** which is configured to perform one or more functions described herein such as determining an interruption time, Td, being a function of a switching delay and first timing advance and a second timing advance.

Example implementations, in accordance with an embodiment, of the wireless device **22**, network node **16** and host computer **24** discussed in the preceding paragraphs will now be described with reference to FIG. **7**. In a communication system **10**, a host computer **24** comprises hardware (HW) **38** including a communication interface **40** configured to set up and maintain a wired or wireless connection with an interface of a different communication device of the communication system **10**. The host computer **24** further comprises processing circuitry **42**, which may have storage and/or processing capabilities. The processing circuitry **42** may include a processor **44** and memory **46**. In particular, in addition to a traditional processor and memory, the processing circuitry **42** may comprise integrated circuitry for pro-

cessing and/or control, e.g., one or more processors and/or processor cores and/or FPGAs (Field Programmable Gate Array) and/or ASICs (Application Specific Integrated Circuitry) adapted to execute instructions. The processor **44** may be configured to access (e.g., write to and/or read from) memory **46**, which may comprise any kind of volatile and/or nonvolatile memory, e.g., cache and/or buffer memory and/or RAM (Random Access Memory) and/or ROM (Read-Only Memory) and/or optical memory and/or EPROM (Erasable Programmable Read-Only Memory).

Processing circuitry **42** may be configured to control any of the methods and/or processes described herein and/or to cause such methods, and/or processes to be performed, e.g., by host computer **24**. Processor **44** corresponds to one or more processors **44** for performing host computer **24** functions described herein. The host computer **24** includes memory **46** that is configured to store data, programmatic software code and/or other information described herein. In some embodiments, the software **48** and/or the host application **50** may include instructions that, when executed by the processor **44** and/or processing circuitry **42**, causes the processor **44** and/or processing circuitry **42** to perform the processes described herein with respect to host computer **24**. The instructions may be software associated with the host computer **24**.

The software **48** may be executable by the processing circuitry **42**. The software **48** includes a host application **50**. The host application **50** may be operable to provide a service to a remote user, such as a wireless device **22** connecting via an OTT connection **52** terminating at the wireless device **22** and the host computer **24**. In providing the service to the remote user, the host application **50** may provide user data which is transmitted using the OTT connection **52**. The "user data" may be data and information described herein as implementing the described functionality. In one embodiment, the host computer **24** may be configured for providing control and functionality to a service provider and may be operated by the service provider or on behalf of the service provider. The processing circuitry **42** of the host computer **24** may enable the host computer **24** to observe, monitor, control, transmit to and/or receive from the network node **16** and or the wireless device **22**.

The communication system **10** further includes a network node **16** provided in a communication system **10** and comprising hardware **58** enabling it to communicate with the host computer **24** and with the wireless device **22**. The hardware **58** may include a communication interface **60** for setting up and maintaining a wired or wireless connection with an interface of a different communication device of the communication system **10**, as well as a radio interface **62** for setting up and maintaining at least a wireless connection **64** with a wireless device **22** located in a coverage area **18** served by the network node **16**. The radio interface **62** may be formed as or may include, for example, one or more RF transmitters, one or more RF receivers, and/or one or more RF transceivers. The communication interface **60** may be configured to facilitate a connection **66** to the host computer **24**. The connection **66** may be direct or it may pass through a core network **14** of the communication system **10** and/or through one or more intermediate networks **30** outside the communication system **10**.

In the embodiment shown, the hardware **58** of the network node **16** further includes processing circuitry **68**. The processing circuitry **68** may include a processor **70** and a memory **72**. In particular, in addition to a traditional processor and memory, the processing circuitry **68** may comprise integrated circuitry for processing and/or control, e.g., one or more processors and/or processor cores and/or FPGAs (Field Programmable Gate Array) and/or ASICs (Application Specific Integrated Circuitry) adapted to execute instructions. The processor **70** may be configured to access (e.g., write to and/or read from) the memory **72**, which may comprise any kind of volatile and/or nonvolatile memory, e.g., cache and/or buffer memory and/or RAM (Random Access Memory) and/or ROM (Read-Only Memory) and/or optical memory and/or EPROM (Erasable Programmable Read-Only Memory).

Thus, the network node **16** further has software **74** stored internally in, for example, memory **72**, or stored in external memory (e.g., database) accessible by the network node **16** via an external connection. The software **74** may be executable by the processing circuitry **68**. The processing circuitry **68** may be configured to control any of the methods and/or processes described herein and/or to cause such methods, and/or processes to be performed, e.g., by network node **16**. Processor **70** corresponds to one or more processors **70** for performing network node **16** functions described herein. The memory **72** is configured to store data, programmatic software code and/or other information described herein. In some embodiments, the software **74** may include instructions that, when executed by the processor **70** and/or processing circuitry **68**, causes the processor **70** and/or processing circuitry **68** to perform the processes described herein with respect to network node **16**. For example, processing circuitry **68** of the network node **16** may include an interrupt duration determination unit **32** configured to determine a duration of an interruption based on temporal parameter, Tz. The processing circuitry **68** may also include a transmission determination module **76** configured to determine the new transmission contained in the received signal based on the determined duration of the interruption.

The communication system **10** further includes the wireless device **22** already referred to. The wireless device **22** may have hardware **80** that may include a radio interface **82** configured to set up and maintain a wireless connection **64** with a network node **16** serving a coverage area **18** in which the wireless device **22** is currently located. The radio interface **82** may be formed as or may include, for example, one or more RF transmitters, one or more RF receivers, and/or one or more RF transceivers.

The hardware **80** of the wireless device **22** further includes processing circuitry **84**. The processing circuitry **84** may include a processor **86** and memory **88**. In particular, in addition to a traditional processor and memory, the processing circuitry **84** may comprise integrated circuitry for processing and/or control, e.g., one or more processors and/or processor cores and/or FPGAs (Field Programmable Gate Array) and/or ASICs (Application Specific Integrated Circuitry) adapted to execute instructions. The processor **86** may be configured to access (e.g., write to and/or read from) memory **88**, which may comprise any kind of volatile and/or nonvolatile memory, e.g., cache and/or buffer memory and/or RAM (Random Access Memory) and/or ROM (Read-Only Memory) and/or optical memory and/or EPROM (Erasable Programmable Read-Only Memory).

Thus, the wireless device **22** may further comprise software **90**, which is stored in, for example, memory **88** at the wireless device **22**, or stored in external memory (e.g., database) accessible by the wireless device **22**. The software **90** may be executable by the processing circuitry **84**. The software **90** may include a client application **92**. The client application **92** may be operable to provide a service to a human or non-human user via the wireless device **22**, with the support of the host computer **24**. In the host computer **24**,

an executing host application **50** may communicate with the executing client application **92** via the OTT connection **52** terminating at the wireless device **22** and the host computer **24**. In providing the service to the user, the client application **92** may receive request data from the host application **50** and provide user data in response to the request data. The OTT connection **52** may transfer both the request data and the user data. The client application **92** may interact with the user to generate the user data that it provides.

The processing circuitry **84** may be configured to control any of the methods and/or processes described herein and/or to cause such methods, and/or processes to be performed, e.g., by wireless device **22**. The processor **86** corresponds to one or more processors **86** for performing wireless device **22** functions described herein. The wireless device **22** includes memory **88** that is configured to store data, programmatic software code and/or other information described herein. In some embodiments, the software **90** and/or the client application **92** may include instructions that, when executed by the processor **86** and/or processing circuitry **84**, causes the processor **86** and/or processing circuitry **84** to perform the processes described herein with respect to wireless device **22**. For example, the processing circuitry **84** of the wireless device **22** may include an interrupt duration determination unit **34** configured to determine an interruption time, Td, being a function of a switching delay and first timing advance and a second timing advance. The processing circuitry **84** may also include switching unit **94** configured to stop the first transmission and start the second transmission such that the delay between the stopping and the starting does not exceed Td.

In some embodiments, the inner workings of the network node **16**, wireless device **22**, and host computer **24** may be as shown in FIG. **7** and independently, the surrounding network topology may be that of FIG. **6**.

In FIG. **7**, the OTT connection **52** has been drawn abstractly to illustrate the communication between the host computer **24** and the wireless device **22** via the network node **16**, without explicit reference to any intermediary devices and the precise routing of messages via these devices. Network infrastructure may determine the routing, which it may be configured to hide from the wireless device **22** or from the service provider operating the host computer **24**, or both. While the OTT connection **52** is active, the network infrastructure may further take decisions by which it dynamically changes the routing (e.g., on the basis of load balancing consideration or reconfiguration of the network).

The wireless connection **64** between the wireless device **22** and the network node **16** is in accordance with the teachings of the embodiments described throughout this disclosure. One or more of the various embodiments improve the performance of OTT services provided to the wireless device **22** using the OTT connection **52**, in which the wireless connection **64** may form the last segment. More precisely, the teachings of some of these embodiments may improve the data rate, latency, and/or power consumption and thereby provide benefits such as reduced user waiting time, relaxed restriction on file size, better responsiveness, extended battery lifetime, etc.

In some embodiments, a measurement procedure may be provided for the purpose of monitoring data rate, latency and other factors on which the one or more embodiments improve. There may further be an optional network functionality for reconfiguring the OTT connection **52** between the host computer **24** and wireless device **22**, in response to variations in the measurement results. The measurement procedure and/or the network functionality for reconfiguring the OTT connection **52** may be implemented in the software **48** of the host computer **24** or in the software **90** of the wireless device **22**, or both. In embodiments, sensors (not shown) may be deployed in or in association with communication devices through which the OTT connection **52** passes; the sensors may participate in the measurement procedure by supplying values of the monitored quantities exemplified above, or supplying values of other physical quantities from which software **48**, **90** may compute or estimate the monitored quantities. The reconfiguring of the OTT connection **52** may include message format, retransmission settings, preferred routing etc.; the reconfiguring need not affect the network node **16**, and it may be unknown or imperceptible to the network node **16**. Some such procedures and functionalities may be known and practiced in the art. In certain embodiments, measurements may involve proprietary wireless device signaling facilitating the host computer's **24** measurements of throughput, propagation times, latency and the like. In some embodiments, the measurements may be implemented in that the software **48**, **90** causes messages to be transmitted, in particular empty or 'dummy' messages, using the OTT connection **52** while it monitors propagation times, errors etc.

Although FIGS. **6** and **7** show various "units" such as interrupt duration determination unit **32**, and interrupt duration determination unit **34** as being within a respective processor, it is contemplated that these units may be implemented such that a portion of the unit is stored in a corresponding memory within the processing circuitry. In other words, the units may be implemented in hardware or in a combination of hardware and software within the processing circuitry.

FIG. **8** is a block diagram of an alternative host computer **24**, which may be implemented at least in part by software modules containing software executable by a processor to perform the functions described herein. The host computer **24** include a communication interface module **41** configured to set up and maintain a wired or wireless connection with an interface of a different communication device of the communication system **10**. The memory module **47** is configured to store data, programmatic software code and/or other information described herein.

FIG. **9** is a block diagram of an alternative network node **16**, which may be implemented at least in part by software modules containing software executable by a processor to perform the functions described herein. The network node **16** includes a radio interface module **63** configured for setting up and maintaining at least a wireless connection **64** with a wireless device **22** located in a coverage area **18** served by the network node **16**. The network node **16** also includes a communication interface module **61** configured for setting up and maintaining a wired or wireless connection with an interface of a different communication device of the communication system **10**. The communication interface module **61** may also be configured to facilitate a connection **66** to the host computer **24**. The memory module **73** that is configured to store data, programmatic software code and/or other information described herein. The interrupt duration determination module **33** is configured to determine a duration of an interruption based on temporal parameter Tz, defined below. The transmission determination module **77** is configured to determine the new transmission contained in the received signal based on the determined duration of the interruption.

FIG. **10** is a block diagram of an alternative wireless device **22**, which may be implemented at least in part by software modules containing software executable by a pro-

cessor to perform the functions described herein. The wireless device **22** includes a radio interface module **83** configured to set up and maintain a wireless connection **64** with a network node **16** serving a coverage area **18** in which the wireless device **22** is currently located. The memory module **89** is configured to store data, programmatic software code and/or other information described herein. The interrupt duration determination module **35** is configured to determine an interruption time, Td, being a function of a switching delay and first timing advance and a second timing advance. The switching module **95** is configured to stop the first transmission and start the second transmission such that the delay between the stopping and the starting does not exceed Td.

FIG. **11** is a flowchart illustrating an exemplary method implemented in a communication system, such as, for example, the communication system of FIGS. **6** and **7**, in accordance with one embodiment. The communication system may include a host computer **24**, a network node **16** and a wireless device **22**, which may be those described with reference to FIG. **7**. In a first step of the method, the host computer **24** provides user data (Block S**100**). In an optional substep of the first step, the host computer **24** provides the user data by executing a host application, such as, for example, the host application **74** (Block S**102**). In a second step, the host computer **24** initiates a transmission carrying the user data to the wireless device **22** (Block S**104**). In an optional third step, the network node **16** transmits to the wireless device **22** the user data which was carried in the transmission that the host computer **22** initiated, in accordance with the teachings of the embodiments described throughout this disclosure (Block S**106**). In an optional fourth step, the wireless device **22** executes a client application, such as, for example, the client application **114**, associated with the host application **74** executed by the host computer **24** (Block S**108**).

FIG. **12** is a flowchart illustrating an exemplary method implemented in a communication system, such as, for example, the communication system of FIG. **6**, in accordance with one embodiment. The communication system may include a host computer **24**, a network node **16** and a wireless device **22**, which may be those described with reference to FIGS. **6** and **7**. In a first step of the method, the host computer **24** provides user data (Block S**110**). In an optional substep (not shown) the host computer **24** provides the user data by executing a host application, such as, for example, the host application **74**. In a second step, the host computer **24** initiates a transmission carrying the user data to the wireless device **22** (Block S**112**). The transmission may pass via the network node **16**, in accordance with the teachings of the embodiments described throughout this disclosure. In an optional third step, the wireless device **22** receives the user data carried in the transmission (Block S**114**).

FIG. **13** is a flowchart illustrating an exemplary method implemented in a communication system, such as, for example, the communication system of FIG. **6**, in accordance with one embodiment. The communication system may include a host computer **24**, a network node **16** and a wireless device **22**, which may be those described with reference to FIGS. **6** and **7**. In an optional first step of the method, the wireless device **22** receives input data provided by the host computer **24** (Block S**116**). In an optional substep of the first step, the wireless device **22** executes the client application **114**, which provides the user data in reaction to the received input data provided by the host computer **24** (Block S**118**). Additionally or alternatively, in an optional second step, the wireless device **22** provides user data (Block S**120**). In an optional substep of the second step, the wireless device **22** provides the user data by executing a client application, such as, for example, client application **114** (Block S**122**). In providing the user data, the executed client application **114** may further consider user input received from the user. Regardless of the specific manner in which the user data was provided, the wireless device **22** may initiate, in an optional third substep, transmission of the user data to the host computer **24** (Block S**124**). In a fourth step of the method, the host computer **24** receives the user data transmitted from the wireless device **22**, in accordance with the teachings of the embodiments described throughout this disclosure (Block S**126**).

FIG. **14** is a flowchart illustrating an exemplary method implemented in a communication system, such as, for example, the communication system of FIG. **6**, in accordance with one embodiment. The communication system may include a host computer **24**, a network node **16** and a wireless device **22**, which may be those described with reference to FIGS. **6** and **7**. In an optional first step of the method, in accordance with the teachings of the embodiments described throughout this disclosure, the network node **16** receives user data from the wireless device **22** (Block S**128**). In an optional second step, the network node **16** initiates transmission of the received user data to the host computer **24** (Block S**130**). In a third step, the host computer **24** receives the user data carried in the transmission initiated by the network node **16** (Block S**132**).

FIG. **15** is a flowchart of an exemplary process in a network node **16** for communicating with a wireless device. The process includes transmitting, via the radio interface **62**, a message to the wireless device at a reference time, Ty, instructing the wireless device to stop transmission in a first cell on a first uplink carrier and start a new transmission in a second cell on a second uplink carrier (Block S**134**). The process includes receiving, via the radio interface **62**, a signal including the new transmission in the second cell on the second uplink carrier within a certain time Tz starting from the reference time, Ty (Block S**136**). The process also includes determining, via the interrupt duration determination unit **32**, a duration of an interruption based on Tz (Block S**138**). The process also includes determining, via the transmission determination unit **76**, the new transmission contained in the received signal based on the determined duration of the interruption (Block S**140**). For example, determining the start of an UL data transmission within a detected UL signal. In one or more embodiments, Tz and/or the duration of the interruption time are one or more examples of one or more timing values that may be associated with one or more cells, cell groups and/or timing advance groups. While FIG. **15** is described with respect to a network node **16** that provides both a first cell and a second cell (i.e., provides multiple cell groups), in one or more embodiments, Blocks S**134** and S**136** are performed by different network nodes **16** such that a first network node **16** providing a first cell instructs the wireless device **22**, as described above, and the second network node **16** providing a second cell receives the new transmission. In one or more embodiments, the first network node **16** and second network node **16** may communicate information with each other via an X2 interface such as timing information of one or more cells.

FIG. **16** is a flowchart of another exemplary process in a network node **16**. One or more Blocks and/or functions performed by network node **16** may be performed by one or more elements of network node **16** such as by interrupt

duration determination unit **32** and/or transmission determination unit **76** in processing circuitry **68**, processor **70**, radio interface **62**, etc. In one or more embodiments, network node **16** such as via one or more of processing circuitry **68**, processor **70**, communication interface **60** and radio interface **62** is configured to receive (Block S**142**) a transmission from a wireless device (**22**) after a time period following a switching of a transmission from a second cell being part of a second cell group, the first cell group being different from the second cell group. The network node **16** may be in control of both the first cell group and the second cell group. In other examples the network node **16** is only in control of the first cell group and the second cell group is controlled by a different network node **16**. In one or more embodiments, network node **16** such as via one or more of processing circuitry **68**, processor **70**, communication interface **60** and radio interface **62** is configured to determine (Block S**144**) a timing value corresponding to the time period, the time value being associated at least in part with the second cell group.

In one or more embodiments, the time period is determined by the network node **16** in response to a message sent to the wireless device **22** to instruct the wireless device **22** to stop transmission in the second cell and start a new transmission in the first cell. In one or more embodiments, the first cell and the second cell are provided by a first network node **16** and a second network node **16**, respectively, and the wireless device **22** is instructed to start the new transmission in the first cell at a reference time, Ty, by the second network node **16** and the determining of the time period is based on the first network node **16** receiving an indication of the reference time, Ty from the second network node **16**.

In one or more embodiments, the timing value is based at least in part on a timing advance of the second cell group and a timing advance of the first cell group. In one or more embodiments, the timing value is based at least in part on a radio frequency, RF, switching time of the wireless device **22**. In one or more embodiments, the timing value is a function of at least one of a radio frequency, RF, switching time of the wireless device **22**, a timing advance of the first cell group and a timing advance of the second cell group. In one or more embodiments, the timing value is based at least in part on at least one of a sum, difference, maximum and product of at least two of: the RF switching time of the wireless device **22**; the timing advance of the first cell group; the timing advance of the second cell group; and the function of at least one of the RF switching time of the wireless device **22**, the timing advance of the first cell group and the timing advance of the second cell group

In one or more embodiments, the timing value is further based at least in part on an error due to one of reception and transmission at the wireless device **22**. In one or more embodiments, the timing value is further based at least in part on an autonomous timing adjustment delay of the wireless device **22**. In one or more embodiments, the first cell is associated with a first radio access technology, RAT, and the second cell is associated with a second RAT different from the first RAT In one or more embodiments, the processing circuitry **68** is further configured to adapt (Block S**145**) a scheduling of transmissions based at least in part on the time period and/or the timing value.

FIG. **17** is a flowchart of yet another exemplary process in a network node **16**. One or more Blocks and/or functions performed by network node **16** may be performed by one or more elements of network node **16** such as by interrupt duration determination unit **32** and/or transmission determination unit **76** in processing circuitry **68**, processor **70**, radio interface **62**, etc. In one or more embodiments, network node **16** such as via one or more of processing circuitry **68**, processor **70**, communication interface **60** and radio interface **62** is configured to transmit (Block S**146**) a message configured to cause the wireless device (**22**) to switch from transmission on the first carrier of the first cell to transmission on a second carrier of a second cell based at least in part on a timing value associated with the second cell, the second cell being part of a second cell group different from the first cell group. The network node **16** may be in control of both the first cell group and the second cell group. In other examples the network node **16** is only in control of the first cell group and the second cell group is controlled by a different network node **16**.

In one or more embodiments, the message is one of a radio resource control message, medium access control message and layer 1 message. In one or more embodiments, the processing circuitry **68** is further configured to determine a reference time, Ty, at which the wireless device **22** is to start transmission on the second carrier of the second cell, the reference time, Ty, is indicated in the message. In one or more embodiments, the timing value is based at least in part on a timing advance of the second cell group and a timing advance of the first cell group. In one or more embodiments, the timing value is based at least in part on a radio frequency, RF, switching time of the wireless device **22**.

In one or more embodiments, the timing value corresponds to a delay in uplink transmission, at least a portion of the delay in the uplink transmission being applied to at least one of an uplink transmission in the first cell and an uplink transmission in the second cell. In one or more embodiments, the timing value is a function of at least one of a radio frequency, RF, switching time of the wireless device **22**, a timing advance of the first cell group and a timing advance of the second cell group. In one or more embodiments, the timing value is based at least in part on at least one of a sum, difference, maximum and product of at least two of: the RF switching time of the wireless device **22**; the timing advance of the first cell group; the timing advance of the second cell group; and the function of at least one of the RF switching time of the wireless device **22**, the timing advance of the first cell group and the timing advance of the second cell group. In one or more embodiments, the timing value is further based at least in part on an error due to one of reception and transmission at the wireless device **22**.

In one or more embodiments, the timing value is further based at least in part on an autonomous timing adjustment delay of the wireless device **22**. In one or more embodiments, the first cell is associated with a first radio access technology, RAT, and the second cell is associated with a second RAT different from the first RAT.

While FIGS. **16** and **17** are described as separate processes, in one or more embodiments, FIGS. **16** and **17** may be performed by a network node **16** that provides both the first cell and the second cell. For example, in a single network node **16**, the process may be performed in the following order: Block S**146**, Block S**142**, Block S**144** and Block S**145**, where one or more Blocks may overlap or optionally be skipped.

In one or more embodiments, network node **16** schedules an UL transmission on a second cell to a wireless device **22** that is currently operating in the first cell, where the scheduling is determined based at least in part on a time delay in switching, as described herein. The scheduling may include transmission of a message and/or command message related to switching as described herein.

FIG. **18** is a flowchart of an exemplary process in a wireless device **22** for communication with a network node **16**. The process includes receiving, via the radio interface **82**, from the network node **16** a message instructing the wireless device **22** to stop a first transmission in a first cell on a first uplink carrier and start a second transmission in a second cell on a second uplink carrier (Block S**148**). The process also includes determining, via the interrupt duration determination unit **34**, an interruption time, Td, being a function of a switching delay and first timing advance and a second timing advance (Block S**150**). The process also includes, via the switching unit **94**, stopping the first transmission and starting the second transmission such that the delay between the stopping and the starting does not exceed Td (Block S**152**).

One scenario may occur when a wireless device **22** is configured for multi-connectivity operation involving at least two cell groups, e.g., a first cell group (CG1) and a second cell group (CG2). The wireless device **22** is configured with at least one serving cell in each of the configured CGs. For example, the wireless device **22** is configured with at least a first cell (cell1) in CG1 and a second cell (cell2) in CG2. Examples of cell1 and cell2 are PCell and PSCell respectively. Other examples of cell1 and cell2 are PSCell and PCell respectively. One or more cells belonging to each cell group are managed or configured or operated by one network node **16**. For example, cells belonging to CG1 and cells belonging to CG2 are managed or configured or operated by a first network node **16** (NW1) and a second network node **16** (NW2), respectively. Cells in the same CG are associated with the same timing advance group (TAG). Cells within the same TAG transmit signals using the same TA value. For example, cells in CG1 and CG2 are associated with TAG1 and TAG2, respectively. The wireless device **22** uses a first timing advance value (TA1) and a second timing advance value (TA2) for transmitting signals on cells (e.g. cell1) in TAG1 and on cells (e.g. cell2) in TAG2, respectively. One of the TAGs is called as pTAG corresponding to a PCell, while other TAGs are called sTAG corresponding to at least one PSCell. The values of TA1 and TA2 are received by the wireless device **22** from the network node **16**, e.g., TA1 is received from NW1 and TA2 is received from NW2.

FIG. **19** is a flowchart of another exemplary process in a wireless device **22**. One or more Blocks and/or functions performed by wireless device **22** may be performed by one or more elements of wireless device **22** such as by interrupt duration determination unit **34** and/or switching unit **94** in processing circuitry **84**, processor **86**, radio interface **82**, etc. In one or more embodiments, wireless device **22** such as via one or more of processing circuitry **84**, processor **86** and radio interface **82** is configured to determine (Block S**154**) a timing value, the timing value being associated with the first cell and second cell. In one or more embodiments, wireless device **22** such as via one or more of processing circuitry **84**, processor **86** and radio interface **82** is configured to stop (Block S**156**) a first transmission in the first cell on the first carrier. In one or more embodiments, wireless device **22** such as via one or more of processing circuitry **84**, processor **86** and radio interface **82** is configured to switch (Block S**158**) to perform a second transmission in a second cell on the second carrier after a time period corresponding to a timing value, the timing value being associated with the first cell and the second cell.

In one or more embodiments, the processing circuitry **84** is further configured to receive a message from the first cell where the stopping of the first transmission in the first cell and the performing of the second transmission in the second cell being in response to the message. In one or more embodiments, the message includes an indication to apply at least a portion of a delay in transmission to at least one of an uplink transmission in the first cell and an uplink transmission in the second cell, the delay corresponding to the timing value. In one or more embodiments, the processing circuitry **84** is further configured to determine whether a predefined rule is met, the stopping of the first transmission in the first cell and the performing of the second transmission in the second cell being in response to the predefined rule being met.

In one or more embodiments, the predefined rule is based on one of a numerology of a signal and predefined time period. In one or more embodiments, the message is one of a radio resource control message, medium access control message and layer 1 message. In one or more embodiments, the timing value is based at least in part on a timing advance of the second cell group and a timing advance of the first cell group. In one or more embodiments, the timing value is based at least in part on a radio frequency, RF, switching time of the wireless device **22**. In one or more embodiments, the timing value is a function of at least one of a radio frequency, RF, switching time of the wireless device **22**, a timing advance of the first cell group and a timing advance of the second cell group.

In one or more embodiments, the timing value is based at least in part on at least one of a sum, difference, maximum and product of at least two of: the RF switching time of the wireless device **22**; the timing advance of the first cell group; the timing advance of the second cell group; and the function of at least one of the RF switching time of the wireless device **22**, the timing advance of the first cell group and the timing advance of the second cell group. In one or more embodiments, the timing value is further based at least in part on an error due to one or reception and transmission at the wireless device **22**. In one or more embodiments, the timing value is further based at least in part on an autonomous timing adjustment delay of the wireless device **22**.

In one or more embodiments, the timing value is based on a timing advance of the second cell group and a timing advance of the first cell group. In one or more embodiments, the first cell and the second cell are provided by a network node **16**. In one or more embodiments, the first cell is associated with a first radio access technology, RAT, and the second cell is associated with a second RAT different from the first RAT.

Having generally described arrangements for adaptation of interruption time due to single transmit operation and/or switching transmission of a wireless device **22** from a first carrier of a first cell to a second carrier of a second cell, details for these arrangements, functions and processes are provided as follows, and which may be implemented by the network node **16**, wireless device **22** and/or host computer **24**. One example of multi-connectivity operation is a multi-connectivity operation involving cells of different RATs, e.g., one or more cells of a first RAT (RAT1) and one or more cells of a second RAT (RAT2). Another example of multi-connectivity operation is a multi-connectivity operation involving the same RAT. Examples of RAT1 and RAT2 are LTE and NR respectively. A special case of multi-connectivity operation is dual connectivity (DC). An example of dual connectivity (DC) is LTE-NR DC (E-UTRA-NR DC (E-N DC)) where CG1 (e.g. LTE CG) and CG2 (e.g. NR CG) are operated or managed by NW1 and NW2, respectively, e.g., NW1 and NW2 are eNode B and gNode B respectively. In one example of E-N DC, the master node is eNode B and secondary node is gNode B. In this case MCG

contains LTE cells while SCG contains NR cells. Furthermore, in this example, the TAG belonging to MCG is pTAG containing LTE cells, while the TAG belonging to SCG is sTAG containing NR cells. In another example of E-N DC, the master node is gNode B and secondary node is eNode B. In this case SCG contains LTE cells while MCG contains NR cells. Furthermore, in this example, the TAG belonging to MCG is pTAG containing NR cells, while the TAG belonging to SCG is sTAG containing LTE cells. In one or more embodiments, the master node and secondary node are two different network nodes **16** that provide respective cells. In one or more embodiments, the master node and secondary node are the same network node **16** that provides respective cells.

In some embodiments, the wireless device **22** is capable of one uplink transmission at a time. This means the wireless device **22** is not allowed to transmit signals in uplink simultaneously in two or more cells. This simultaneous transmission may not be allowed especially if the cells belong to different bands and, in particular, the transmission on these bands will cause an IMD problem. The IMD problem degrades the wireless device **22** reception quality or may even block the wireless device **22** receiver from successfully decoding the received signals.

In multi-connectivity, the wireless device **22** is required to transmit in at least one cell of each CG. Therefore, in case of a single uplink transmission at a time (e.g. non-simultaneous UL), the wireless device **22** may switch between uplink transmission in cell1 (e.g., PCell belonging to LTE TAG such as pTAG) and uplink transmission in cell2 (e.g. PSCell belonging to NR TAG such as sTAG) within a certain time delay (Td).

A method in a wireless device **22** configured with multi-connectivity operation may include the following steps:

- Step-1: Obtaining information to switch uplink transmission of signals between cell1 and cell2 operating on a first UL carrier (UL-CC1) and a second UL carrier (UL-CC2), respectively;
- Step-2: Determining an interruption time (Td) (which may be an example of a timing value) for switching uplink transmission of signals between cell1 and cell2, where Td is function of at least RF switching delay, TA1 and TA2 respectively, which may be one or more examples of a timing value and/or timing parameter; and
- Step-3: Transmitting signals in cell1 and/or cell2 while interrupting the signals transmitted between the wireless device **22** and cell1 and/or between the wireless device **22** and cell2 over a duration which does not exceed Td. In one or more embodiments, the interruption time corresponds to a delay between stopping transmission on a first carrier in a first cell and starting transmission on second carrier in a second cell where at least a portion of this delay may be applied to the transmission in the first cell and/or second cell. In one or more embodiments, this delay corresponds to a delay between consecutive UL transmissions from the wireless device **22**. These steps are discussed in further detail below.

Step 1

In this step, the wireless device **22** may obtain information that the wireless device **22** has to switch uplink transmission of signals between cell1 and cell2 operating on or belonging to a first UL carrier (UL-CC1) and a second UL carrier (UL-CC2), respectively. The wireless device **22** may obtain this information based on any one or more of:

- a pre-defined rule. For example, it can be pre-defined that the wireless device **22** has to switch the uplink transmission after a certain time period, e.g., once every N number of slots or M number of frames, or periodically, or whenever the wireless device **22** has to transmit signals in the UL on any cell, or based on a timer such as the wireless device **22** is not allowed to transmit in etc.; and/or
- information received from a network node **16** (e.g., NW1, NE2 or another network node **16**). For example, the received information is based on a command or message. Examples of the command or the message are RRC message, MAC command, L1 message (e.g. DCI, etc.). In one or more embodiments, the information is received in a message that is configured to cause the wireless device **22** to switch from transmission on the first carrier of the first cell to transmission on a second carrier on a second cell based at least in part on a timing value associated with the second cell, as described herein.

In one example based on the obtained information, the wireless device **22** may stop transmission of signals in cell1 at a certain time instance and starts transmission of signals in cell2 at the same or different time instance. In another example, based on the obtained information the wireless device **22** may stop transmission of signals in cell2 at a certain time instance and starts transmission of signals in cell1 at the same or different time instance. In one or more embodiments, the information may include additional data used by the wireless device **22** for determining an interruption time (Td) described below, where the additional data may include an indication of the interruption time and/or other timing parameters described herein.

Step 2

While switching the uplink transmission of signals between cell1 and cell2, there may be interruption of signals transmitted between the wireless device **22** and cell1 and/or between the wireless device **22** and cell2. The interruption may also occur on signals transmitted between: the wireless device **22** and the DL of cell1 and/or the wireless device **22** and the DL of cell2. The interruption may also occur on signals transmitted between: the wireless device **22** and one or more additional cells (i.e., other than cell1) belonging to CG1 and/or between the wireless device **22** and one or more additional cells (i.e., other than cell2) belonging to CG2.

The maximum duration over which the interruption occurs may not exceed the time period (Td). This interruption time (Td) (i.e., an example of a timing value), due to switching uplink transmission of signals between cell1 and cell2, may be a function of at least the following parameters:

wireless device **22** RF switching time (Tr);
a first timing advance (TA1) in TAG1; and
a second timing advance (TA2) in TAG2.

Examples of Tr are 0 μs, 50 μs, 100 μs, 200 μs, 900 μs, 1000 μs, etc. Examples of TA1 and TA2 are 0, 1 μs, 2 μs, 15 μs, 17 μs, etc. One or more of these parameters are one or more examples of one or more timing values where Td is a timing value that is based on one or more other timing values, for example.

The interruption time, Td, can be expressed by a function of parameters Tr, TA1 and TA2. Examples of function are sum, maximum, product. etc. The Td can be expressed in a suitable time unit, e.g., in seconds, ms, μs, or other basic time unit. Examples of basic time units are Ts, Tc, etc., where 1 Ts=32.55 ns and 1 Tc=Ts/64.

An example of a general function of Td is expressed in (1):

$$Td=f(Tr,TA1,TA2) \quad (1)$$

The value of Td may further be a function of an additional parameter. e.g., an implementation margin in the wireless device **22** (Tm). This time (Tm) is used to account for implementation error, e.g., error due to reception and/or transmission of signals. Examples of Tm are 0, 20 μs, 50 μs and 100 μs. Tm may also account for the time required to synchronize to the target cell, (e.g., to cell2 when switching from cell1 to cell2 or to cell1 when switching from cell2 to cell1). If the target cell is fully synchronized, then Tm=0; otherwise it is larger than 0. Examples of procedures or operations required by the wireless device **22** for synchronizing to the target cell are: time tracking, frequency tracking, settling of automatic gain controller (AGC), performing automatic frequency correction (AFC) especially when wireless device **22** speed is above threshold (e.g. more than 90 km/hour), etc. The value of Tm may further be dependent on the type of reference signals used for performing synchronization with respect to the target cell. Examples of these types of reference signals (RSs) are PSS, SSS, demodulation reference signal (DMRS), tracking reference signal (TRS), channel state information reference signal (CSI-RS), etc. For example, the occurrence (e.g., periodicity and/or density, e.g., number of RSs per time-frequency resource) may impact the value of Tm. For example, if the reference signal (RS) is more frequent (e.g., once every 5 ms) and/or is more dense (e.g., at least 2 resource elements every resource block), then the Tm will be shorter (e.g., shorter than or equal to a certain threshold value); otherwise Tm will be larger than the threshold value. In one or more embodiments, Tm and/or Td may correspond to a time period based at least in part on a timing value and/or parameter.

Another example of a general function including Tr is expressed in (2):

$$Td=f(Tr,TA1,TA2,Tm) \quad (2)$$

An example of a specific function is expressed in (3):

$$Td=Tr+Tm+f1(TA1,TA2) \quad (3)$$

An example of a specific function when TA1>TA2 is expressed in (4):

$$Td=Tr+Tm+(TA1-TA2) \quad (4)$$

Another example of a specific function when TA2>TA1 is expressed in (5):

$$Td=Tr+Tm+(TA2-TA1) \quad (5)$$

The value of Td (i.e., an example of a timing value) may further be a function of one or more additional parameters, for example:

- a first autonomous timing adjustment delay or error in cell1 (Tb1); and/or
- a second autonomous timing adjustment delay or error in cell2 (Tb2).

Examples of Tb1 and Tb2 are 0, 0.5 μs, 1 μs, 2 μs, 3 μs, etc.

The autonomous timing adjustment delay is also called the wireless device **22** initial transmit timing error. This timing error occurs on the uplink transmission, which typically occurs at a first transmission or when the wireless device **22** does not have a valid TA command for adjusting its timing. The first transmission takes place when there is initial transmission (e.g., random access), transmission after long inactivity (e.g., when the time alignment timer (TAT) has expired), first transmission during the DRX cycle, etc. In this case, the wireless device **22** autonomously derives its uplink timing for uplink transmission based on the DL timing of a DL cell, e.g., based on a DL reference signal used in the DL cell. Examples of DL RS are PSS, SSS, CSI-RS, DMRS etc.

The interruption time, Td, can be also expressed by a function. An example of a general function is expressed in (6):

$$Td=f(Tr,TA1,TA2,Tm,Tb1,Tb2) \quad (6)$$

An example of a specific function that also takes into account Tb1 and Tb2 is expressed in (7):

$$Td=Tr+Tm+f1(TA1,TA2,Tb1,Ts2) \quad (7)$$

An example of a specific function when TA1>TA2 and Tb1>Tb2 is expressed in (8):

$$Td=Tr+Tm+(TA1-TA2)+(Tb1-Tb2) \quad (8)$$

An example of a specific function when TA1<TA2 and Tb1<Tb2 is expressed in (9):

$$Td=Tr+Tm+(TA2-TA1)+(Tb2-Tb1) \quad (9)$$

If the procedure of switching the uplink transmission between cell1 and cell2 is triggered by the network node **16** then the wireless device **22** may receive a message or command from the network node **16** to perform the switching at certain reference time, Ty. The wireless device **22** needs time to process the message, e.g., over a duration of Tz. In this case, the time between the wireless device **22** receiving the message and the moment the wireless device **22** completes the switching corresponds to a total time of: Tz+Td. Tz is a processing time for processing the message. Examples of Tz are 15 ms, 20 ms, etc. During Tz, the wireless device **22** may not cause any interruption.

Step 3

In this step, the wireless device **22** may transmit signals in cell1 and/or in cell2 while interrupting the signals transmitted between the wireless device **22** and cell1 and/or between the wireless device **22** and cell2 over a duration which may not exceed Td. The wireless device **22** may cause interruption on signals transmitted: either between the wireless device **22** and cell1, or between the wireless device **22** and cell2 or between the wireless device **22** and both cell1 and cell2. The cells which are interrupted may be determined by the wireless device **22** based on one or more rules. The rules can be determined or obtained by the wireless device **22** by means of one or more of the following:

- based on a predefined rule; and/or
- based on instruction or message or command received from a network node **16**, e.g., from NW1, NW2 or from another network node **16**.

A general example of the rule is illustrated in TABLE 3. In one example, the wireless device **22** can be configured (e.g., based on a message received from the network node **16** or pre-defined criteria), whether the wireless device **22** will cause the entire interruption in one or more cells (e.g., cell1) of CG1, entire interruption in one or more cells (e.g., cell2) of CG2, or partial interruption in both CGs. Examples of partial interruption (e.g., 10 or 11) are X1% of Td and (100−X1)% of Td (or X2% of Td and (100−X2)%) in cells of CG1 and cells of CG2, respectively. Examples of X1 and X2 are 80 and 20, respectively.

TABLE 3

Interruption distribution case	Interruption of signals in cells of different CGs (CG1 and CG2) during UL Tx switching between cell1 and cell2: Interruption in cells of CG1 in terms of percentage (%) of total interruption time (Td)	Interruption of signals in cells of different CGs (CG1 and CG2) during UL Tx switching between cell1 and cell2: Interruption in cells of CG2 in terms of percentage (%) of total interruption time (Td)
00	100%	0
01	0	100%
10	X1%	100-X1
11	X2%	100-X2

TABLE 4 gives another specific example of distribution of the absolute value of interruption of signals between the wireless device **22** and cells (e.g., cell1) of CG1 and/or between the wireless device **22** and cells (e.g., cell2) of CG2, assuming X1=80, X2=20, and Td=2 ms.

TABLE 4

Interruption distribution case	Interruption of signals in cells of different CGs (CG1 and CG2) during UL Tx switching between cell1 and cell2: Interruption in cells of CG1 (ms)	Interruption of signals in cells of different CGs (CG1 and CG2) during UL Tx switching between cell1 and cell2: Interruption in cells of CG2 (ms)
00	2 ms	0
01	0	2 ms
10	1.6 ms	0.4 ms
11	0.4 ms	1.6 ms

Examples of criteria for determining or selecting one of the rules (percentage or amount of interruption to occur in cells of CG1 or CG2 or in both CG1 and CG2) are described below.

In one example of the rule, the interruption occurs in cell1 or cell2 or in both cells are based on the type of UL transmission.

- For example, when certain control channel(s) are transmitted in the end of cell1 on UL-CC1, then the interruptions can be placed in cell2 in UL-CC2 transmissions. Similarly, when certain control channel(s) are transmitted at the beginning of the UL-CC2 transmissions, the interruptions can be placed in UL-CC1 transmissions. Examples of control channels may include SRS, DMRS, PTRS, etc., or any other UL channel which need to be protected.
- In one example, when both the end UL symbols of UL-CC1 and beginning UL symbols of UL-CC2 are to be protected, then the interruption time can be shared between two UL CC equally.

In another example of the rule, the interruption occurs in cell1 or cell2, or in both cells, and are based on sub-carrier spacings used in cell1 and cell2. As an example, with smaller subcarrier spacing, the symbol duration may be larger. Therefore, according to one rule, the interruption or part of the interruption occurs in the UL CC with smaller subcarrier spacing (SCS) below or equal to a SCS-threshold (St). An example of St is 30 KHz. This rule may be less harmful in terms of UL throughput loss since a large part of the slot containing UL signals is transmitted by the wireless device **22** without any interruption.

A method in a network node **16** may include the following steps:

- Step-1: transmitting a message or command to a wireless device at a reference time (Ty) for enabling the wireless device **22** to stop transmission in cell1 on a first UL carrier (UL-CC1) and start a new transmission in cell2 on a second UL carrier (UL-CC2) or vice versa.
- Step-2: receiving an UL signal from cell2 on UL-CC2 if the wireless device **22** switches from cell1 to cell2 (or from cell1 on UL-CC1 if the wireless device **22** switches from cell2 to cell1) within a certain time period (Tz) starting from the reference time instance (Ty); and
- Step-3: adapting the received signals based on interruption of signals due to the uplink transmission, e.g., processing the received UL signal according to useful or available part of the signals after interruption. These steps are discussed in detail as follows.

Step-1

In this step, the network node **16** may transmit a message or a command to the wireless device **22** that the wireless device **22** should switch uplink transmission of signals between cell1 and cell2 operating on or belong to a first UL carrier (UL-CC1) and a second UL carrier (UL-CC2), respectively. The network node **16** may further indicate in the message that the wireless device **22**, when switching the UL transmission, should cause interruption in cells of the source CG (e.g., cell1 in CG1 such as MCG) or in the cells of the target CG (e.g. cell2 in CG2 such as SCG) or in both source and target cells (e.g., in cells of both CG1 and CG2).

Examples of the message or command are RRC message, MAC message, L1 message, e.g., sent via DCI on DL control channel, etc. The message or command is transmitted to the wireless device **22** at a certain reference time instance (Ty). Examples of a reference time are the start of certain frame or subframe or time slot, e.g., starting from a certain frame number e.g. SFN=0, SFN=128, etc.

The network node **16** may send the command to the wireless device **22** on the single transmission based on any one or more of:

- the buffer size of cells in CG1 and/or in CG2, e.g., if the traffic in cells in CG2 is above a certain threshold then the network node **16** may request the wireless device **22** to switch UL transmission from cell1 to cell2;
- a pre-defined rule. For example, the wireless device **22** may switch the uplink transmission after a certain time period from one UL cell to another UL cell. Otherwise, the wireless device **22** may suspend UL transmission or go into idle state or lose connection, etc. In this case, the network node **16** sends a command to the wireless device **22** to change the cell for UL transmission, e.g., upon expiration of certain timer. The timer is set when the wireless device **22** starts UL transmission in a cell, e.g., in cell1 or cell2; and/or
- information received from another network node **16** (e.g., NW1, NW2 or another network node **16**). For example NW2 may send a request to NW1 to request the wireless device **22** to switch from cell1 to cell2.

Step-2

In this step, the network node **16** receives the UL transmission in a target cell, e.g., in cell2 on second UL-CC2 from the wireless device **22** if the wireless device **22** has switched from cell1 to cell2 or in cell **1** on UL-CC1 from the wireless device **22** if the wireless device **22** has switched from cell1 to cell2 within a certain time period starting from the reference time (Ty). The duration of the time period includes Ty and Td where Td is described above. Based on the durations Ty and Td, the network node **16** determines the duration of the interruption (Td) of signals which the wire-

less device **22** shall cause in cell1 and/or in cell2 when switching the transmissions between cell1 and cell2. In one or more embodiments, the reference time (Ty) corresponds to a time where the wireless device **22** is to initiating switching or a time where the wireless device **22** is to initiate transmission with the new cell, e.g., cell2 if the wireless device **22** is switched from cell1 to cell2.

Step-3

Based on the information in step-2, the network node **16** may determine the useful part of UL transmissions in the target cell (e.g., in cell2 on UL-CC2) and detects the UL signals accordingly. The network node **16** further adapts the scheduling of signals in cell1 and/or in cell2 based on the received UL signals in the target cell.

SOME EXAMPLES

Example A1

A network node **16** configured to communicate with a wireless device **22** (wireless device **22**), the network node **16** may comprise a radio interface **62** and may comprise processing circuitry **68** configured to:

- transmit a message to the wireless device **22** at a reference time, Ty, instructing the wireless device **22** to stop transmission in a first cell on a first uplink carrier and start a new transmission in a second cell on a second uplink carrier;
- receive a signal including the new transmission in the second cell on the second uplink carrier within a certain time Tz starting from the reference time, Ty;
- determine a duration of an interruption based on Tz; and
- determine the new transmission contained in the received signal based on the determined duration of the interruption.

Example A2

The network node **16** of Example A1, wherein the message is transmitted in response to detecting that traffic in a cell group to which the second cell belongs is above a threshold.

Example A3

The network node **16** of Example A1, wherein the message further instructs the wireless device **22** to switch cells upon expiration of a specified time period.

Example B1

A communication system including a host computer **24**, the host computer **24** may comprise:

- processing circuitry **42** configured to provide user data; and
- a communication interface **40** configured to forward the user data to a cellular network for transmission to a wireless device **22**,
- the cellular network **10** comprising a network node **16** that may have a radio interface **62** and may have processing circuitry **68**, the network node's radio interface **62** and processing circuitry **68** configured to:
  - transmit a message to the wireless device **22** at a reference time, Ty, instructing the wireless device **22** to stop transmission in a first cell on a first uplink carrier and start a new transmission in a second cell on a second uplink carrier;
  - receive a signal including the new transmission in the second cell on the second uplink carrier within a certain time Tz starting from the reference time, Ty;
  - determine a duration of an interruption based on Tz; and
  - determine the new transmission contained in the received signal based on the determined duration of the interruption.

Example B2

The communication system **10** of Example B1, further including the network node **16**.

Example B3

The communication system **10** of Example B2, further including the wireless device **22**, wherein the wireless device **22** is configured to communicate with the network node **16**.

Example B4

The communication system **10** of Example B3, wherein:

- the processing circuitry **42** of the host computer **24** is configured to execute a host application, thereby providing the user data; and
- the wireless device **22** may comprise processing circuitry **84** configured to execute a client application **92** associated with the host application **50**.

Example C1

A method implemented in a network node **16**, the method comprising:

- transmitting a message to the wireless device **22** at a reference time, Ty, instructing the wireless device **22** to stop transmission in a first cell on a first uplink carrier and start a new transmission in a second cell on a second uplink carrier;
- receiving a signal including the new transmission in the second cell on the second uplink carrier within a certain time Tz starting from the reference time, Ty;
- determining a duration of an interruption based on Tz; and
- determining the new transmission contained in the received signal based on the determined duration of the interruption.

Example C2

The method of Example C1, wherein the message is transmitted in response to detecting that traffic in a cell group to which the second cell belongs is above a threshold.

Example C3

The method of Example C1, wherein the message further instructs the wireless device **22** to switch cells upon expiration of a specified time period.

Example D1

A method implemented in a communication system **10** including a host computer **24**, a network node **16** and a wireless device **22**, the method comprising:

- at the host computer **24**, providing user data; and
- at the host computer **24**, initiating a transmission carrying the user data to the wireless device **22** via a cellular

network comprising the network node **16**, the network node **16** configured to:

transmit a message to the wireless device **22** at a reference time, Ty, instructing the wireless device **22** to stop transmission in a first cell on a first uplink carrier and start a new transmission in a second cell on a second uplink carrier;

receive a signal including the new transmission in the second cell on the second uplink carrier within a certain time Tz starting from the reference time, Ty;

determine a duration of an interruption based on Tz; and

determine the new transmission contained in the received signal based on the determined duration of the interruption.

Example D2

The method of Example D1, further comprising, at the network node **16**, transmitting the user data.

Example D3

The method of Example D2, wherein the user data is provided at the host computer **24** by executing a host application **50**, the method further comprising, at the wireless device **22**, executing a client application **92** associated with the host application **50**.

Example E1

A wireless device **22** configured to communicate with a network node **16**, the wireless device **22** may comprise a radio interface **82** and may comprise processing circuitry **84** configured to:

receive from the network node **16** a message instructing the wireless device **22** to stop a first transmission in a first cell on a first uplink carrier and start a second transmission in a second cell on a second uplink carrier;

determine an interruption time, Td, being a function of a switching delay and first timing advance and a second timing advance; and

stop the first transmission and start the second transmission such that the delay between the stopping and the starting does not exceed Td.

Example E2

The wireless device **22** of Example E1, wherein the stopping and the starting occurs after a specified period of time.

Example E3

The wireless device **22** of Example E1, wherein the interruption time Td does not exceed a specified period of time.

Example F1

A communication system **10** including a host computer **24**, the host computer **24** may comprise:

processing circuitry **42** configured to provide user data; and

a communication interface **40** configured to forward user data to a cellular network for transmission to a wireless device **22**,

the wireless device **22** may comprise a radio interface **82** and may comprise processing circuitry **84**, the wireless device's processing circuitry **84** configured to:

receive from the network node **16** a message instructing the wireless device **22** to stop a first transmission in a first cell on a first uplink carrier and start a second transmission in a second cell on a second uplink carrier;

determine an interruption time, Td, being a function of a switching delay and first timing advance and a second timing advance; and

stop the first transmission and start the second transmission such that the delay between the stopping and the starting does not exceed Td.

Example F2

The communication system **10** of Example F1, further including the wireless device **22**.

Example F3

The communication system **10** of Example F2, wherein the cellular network further includes a network node **16** configured to communicate with the wireless device **22**.

Example F4

The communication system **10** of Example F2 or F3, wherein:

the processing circuitry **42** of the host computer **24** is configured to execute a host application **50**, thereby providing the user data; and

the wireless device's processing circuitry **84** is configured to execute a client application **92** associated with the host application **50**.

Example G1

A method implemented in a wireless device **22**, the method comprising:

receiving from the network node **16** a message instructing the wireless device **22** to stop a first transmission in a first cell on a first uplink carrier and start a second transmission in a second cell on a second uplink carrier;

determining an interruption time, Td, being a function of a switching delay and first timing advance and a second timing advance; and

stopping the first transmission and starting the second transmission such that the delay between the stopping and the starting does not exceed Td.

Example G2

The method of Example G1, wherein the stopping and the starting occurs after a specified period of time.

Example G3

The method of Example G1, wherein the interruption time Td does not exceed a specified period of time.

Example H1

A method implemented in a communication system **10** including a host computer **24**, a network node **16** and a wireless device **22**, the method comprising:

at the host computer **24**, providing user data; and

at the host computer **24**, initiating a transmission carrying the user data to the wireless device **22** via a cellular network comprising the network node **16**, the wireless device **22** configured to:

receive from the network node **16** a message instructing the wireless device **22** to stop a first transmission in a first cell on a first uplink carrier and start a second transmission in a second cell on a second uplink carrier;

determine an interruption time, Td, being a function of a switching delay and first timing advance and a second timing advance; and

stop the first transmission and start the second transmission such that the delay between the stopping and the starting does not exceed Td.

Example H2

The method of Example H1, further comprising, at the wireless device **22**, receiving the user data from the network node **16**.

Example I1

A network node **16**, comprising:

a memory module **73** configured to store a message instructing the wireless device **22** to stop transmission in a first cell on a first uplink carrier and start a new transmission in a second cell on a second uplink carrier

a radio interface module **63** configured to:

transmit the message to the wireless device **22**; and

receive a signal including the new transmission in the second cell on the second uplink carrier within a certain time Tz starting from the reference time, Ty; and

an interrupt duration determination module **33** configured to determine a duration of an interruption based on Tz; and

a transmission determination module **77** configured to determine the new transmission contained in the received signal based on the determined duration of the interruption.

Example I2

A wireless device **22**, comprising:

a memory module **89** configured to store a message instructing the wireless device **22** to stop a first transmission in a first cell on a first uplink carrier and start a second transmission in a second cell on a second uplink carrier

a radio interface module **83** configured to receive the message from a network node **16**;

an interrupt duration determination module **35** configured to determine an interruption time, Td, being a function of a switching delay and first timing advance and a second timing advance;

a switching module **95** configured to stop the first transmission and start the second transmission such that the delay between the stopping and the starting does not exceed Td.

As will be appreciated by one of skill in the art, the concepts described herein may be embodied as a method, data processing system, and/or computer program product. Accordingly, the concepts described herein may take the form of an entirely hardware embodiment, an entirely software embodiment or an embodiment combining software and hardware aspects all generally referred to herein as a "circuit" or "module." Furthermore, the disclosure may take the form of a computer program product on a tangible computer usable storage medium having computer program code embodied in the medium that can be executed by a computer. Any suitable tangible computer readable medium may be utilized including hard disks, CD-ROMs, electronic storage devices, optical storage devices, or magnetic storage devices.

Some embodiments are described herein with reference to flowchart illustrations and/or block diagrams of methods, systems and computer program products. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer (to thereby create a special purpose computer), special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

These computer program instructions may also be stored in a computer readable memory or storage medium that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer readable memory produce an article of manufacture including instruction means which implement the function/act specified in the flowchart and/or block diagram block or blocks.

The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide steps for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

It is to be understood that the functions/acts noted in the blocks may occur out of the order noted in the operational illustrations. For example, two blocks shown in succession may in fact be executed substantially concurrently or the blocks may sometimes be executed in the reverse order, depending upon the functionality/acts involved. Although some of the diagrams include arrows on communication paths to show a primary direction of communication, it is to be understood that communication may occur in the opposite direction to the depicted arrows.

Computer program code for carrying out operations of the concepts described herein may be written in an object oriented programming language such as Java® or C++. However, the computer program code for carrying out operations of the disclosure may also be written in conventional procedural programming languages, such as the "C" programming language. The program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer. In the latter scenario, the remote computer may be connected to the user's computer through a local area network (LAN) or a wide area network (WAN), or the

connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

Many different embodiments have been disclosed herein, in connection with the above description and the drawings. It will be understood that it would be unduly repetitious and obfuscating to literally describe and illustrate every combination and subcombination of these embodiments. Accordingly, all embodiments can be combined in any way and/or combination, and the present specification, including the drawings, shall be construed to constitute a complete written description of all combinations and subcombinations of the embodiments described herein, and of the manner and process of making and using them, and shall support claims to any such combination or subcombination.

It will be appreciated by persons skilled in the art that the embodiments described herein are not limited to what has been particularly shown and described herein above. In addition, unless mention was made above to the contrary, it should be noted that all of the accompanying drawings are not to scale. A variety of modifications and variations are possible in light of the above teachings.

The invention claimed is:

1. A method performed by a wireless device configured to communicate on a first carrier with a first cell that is part of a first cell group and on a second carrier with a second cell that is part of a second cell group, the method comprising:

determining a timing value, the timing value being associated with one or both of the first cell and second cell, the timing value being based on an indication from the first cell and a maximum of:

a radio frequency switching time of the wireless device; and

a function of at least one of the RF switching time of the wireless device, a first timing advance of the first cell group and a second timing advance of the second cell group;

receiving a first message configured to cause the wireless device to switch from a first transmission on the first carrier of the first cell to a second transmission on the second carrier of the second cell based at least in part on the determined timing value associated with the second cell;

stopping the first transmission in the first cell on the first carrier; and

switching to perform the second transmission in the second cell on the second carrier after a time period corresponding to the timing value, the stopping of the first transmission in the first cell and the performing of the second transmission in the second cell corresponding to an interruption of downlink signals from the first cell or the second cell.

2. The method of claim **1**, further comprising determining whether a predefined rule is met, the stopping of the first transmission in the first cell and the performing of the second transmission in the second cell being in response to the predefined rule being met, wherein the predefined rule is based on one of a numerology of a signal and predefined time period.

3. The method of claim **1**, wherein the timing value is based at least in part on one or more of:

an error due to one of reception and transmission at the wireless device; and

an autonomous timing adjustment delay of the wireless device.

4. The method of claim **1**, wherein the first cell and the second cell are provided by a network node.

5. The method of claim **1**, wherein the first cell is associated with a first radio access technology, RAT, and the second cell is associated with a second RAT different from the first RAT.

6. The method of claim **1**, wherein the second cell group is different from the first cell group.

7. The method of claim **1**, wherein the method further includes one or both of:

receiving a second message from the first cell, the received second message including the indication, the indication indicating to the wireless device to apply at least a portion of a delay in transmission to at least one of an uplink transmission in the first cell and an uplink transmission in the second cell, the delay corresponding to the timing value; and

switching to perform the second transmission in the second cell on the second carrier after the time period corresponding to the timing value, in response to the second message from the first cell.

8. A wireless device configured to communicate on a first carrier with a first cell that is part of a first cell group and on a second carrier with a second cell that is part of a second cell group, the wireless device comprising:

processing circuitry configured to:

determine a timing value, the timing value being associated with one or both of the first cell and second cell, the timing value being based on an indication from the first cell and a maximum of:

a radio frequency switching time of the wireless device; and

a function of at least one of the RF switching time of the wireless device, a first timing advance of the first cell group and a second timing advance of the second cell group;

receiving a first message configured to cause the wireless device to switch from a first transmission on the first carrier of the first cell to a second transmission on the second carrier of the second cell based at least in part on the determined timing value associated with the second cell;

stop the first transmission in the first cell on the first carrier; and

switch to perform the second transmission in the second cell on the second carrier after a time period corresponding to the timing value, the stopping of the first transmission in the first cell and the performing of the second transmission in the second cell corresponding to an interruption of downlink signals from the first cell or the second cell.

9. The wireless device of claim **8**, wherein the processing circuitry is further configured to determine whether a predefined rule is met, the stopping of the first transmission in the first cell and the performing of the second transmission in the second cell being in response to the predefined rule being met, wherein the predefined rule is based on one of a numerology of a signal and predefined time period.

10. The wireless device of claim **8**, wherein the timing value is based at least in part on one or more of:

an error due to one of reception and transmission at the wireless device; and

an autonomous timing adjustment delay of the wireless device.

11. The method of claim **8**, wherein the second cell group is different from the first cell group.

12. The wireless device of claim 8, wherein the processing circuitry is further configured to one or both of:

receive a second message from the first cell, the received second message including the indication, the indication indicating to the wireless device to apply at least a portion of a delay in transmission to at least one of an uplink transmission in the first cell and an uplink transmission in the second cell, the delay corresponding to the timing value; and

switch to perform the second transmission in the second cell on the second carrier after the time period corresponding to the timing value, in response to the second message from the first cell.

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