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DESCRIPTION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to PCT/CN2017/110528 filed on November 10, 2017.

TECHNICAL FIELD

[0002] The embodiments herein relate generally to wireless communication, and more particularly, the embodiments herein relate to timing advance offset for uplink/downlink switching in New Radio (NR).

BACKGROUND

[0003] In order to preserve the orthogonality in the uplink (UL), the UL transmissions from multiple user equipments (UEs) need to be time aligned at a network node, such as a base station, the eNodeB or the like. This means that the transmit timing of the UEs in the same cell should be adjusted to ensure that their signals arrive at the eNodeB receiver at the same time. In order to perform this adjustment, Timing Advance (TA) is defined to specifying the advance of the uplink frame relative to the downlink (DL) frame.

[0004] In Long-Term Evolution (LTE), TA offset for uplink/downlink switching is further introduced in third Generation Partnership Project (3GPP) Technical Specification TS 36.211. Figure 1 shows conventional timing advance of the uplink transmission before the downlink transmission. As shown in Figure 1, transmission of the uplink radio frame number i from the UE may start $(N_{TA} + N_{TA\ offset}) \times T_s$ seconds before the start of the corresponding downlink radio frame at the UE, where $0 \leq N_{TA} \leq 4096$ if the UE is configured with a Secondary Cell Group (SCG), and $0 \leq N_{TA} \leq 20512$ otherwise. Note that $T_s = 1/ (30.72*10^6)$. For frame structure type 1, $N_{TA\ offset} = 0$, and for frame structure type 2, $N_{TA\ offset} = 624$, unless stated otherwise. Note that not all slots in a radio frame may be transmitted. One example hereof is TDD, where only a subset of the slots in a radio frame is transmitted.
US 2015/0230268 discloses a method in which a timing advance offset value for a user equipment to use for uplink transmissions is determined based on which of FDD and TDD component carriers carries a physical uplink control channel. A 3GPP submission by Ericsson (R4-1708380, "Further Analysis of UE Initial Transmit Timing Requirement") discloses a method in which a maximum autonomous time adjustment step for uplink transmission timing adjustment varies between different transmit frequency ranges.

SUMMARY

[0005] The latest specifications of NR provide no TA offset description for uplink/downlink. Only the TA is considered as below. Downlink and uplink transmissions are organized into frames with $T_f = (\Delta f_{max} N_f/100) \times T_c$ = 10ms duration, consisting of ten subframes of $T_{sf} = (\Delta f_{max} N_f//1000) \times T_c$ = lms duration each. The number of consecutive Orthogonal Frequency Division Multiplexing (OFDM) symbols per subframe is

$$N_{symb}^{subframe,\mu} = N_{symb}^{slot} N_{slot}^{subframe,\mu}$$

Each frame is divided into two equally-sized half-frames of five subframes each with half-frame 0 consisting of subframes 0-4 and half-frame 1 consisting of subframes 5-9. The term "uplink/downlink switching" (alternatively "uplink-downlink switching") can refer to switching from downlink to uplink or uplink to downlink, e.g. in TDD operation.

[0006] There is one set of frames in the uplink and one set of frames in the downlink on a carrier. Figure 2 shows the timing advance of the uplink transmission before the downlink transmission in NR. As shown in Figure 2, transmission of uplink frame number i from the UE shall start $T_{TA} = N_{TA} T_C$ before the start of the corresponding downlink frame at the UE. Note that $T_c = T_s/64 = 1/ (64*30.72*10^6)$.

[0007] So the TA offset should be also considered in TA command itself specified in other specifications or explicitly defined in 38.211 with some constant values for different cases. As a result, some definitions are required to specify the timing reserved for UL/DL switching.

[0008] In 3GPP RAN4, the UE transient time in each direction may be 10μs in below 6GHz bands and 5μs in above 6GHz bands in general. Thus, total switching time for going from DL to UL and UL to DL could be about 20μs for low bands and 10μs for high bands.

[0009] The invention is defined by the claims appended hereto. Examples described herein may introduce TA offset in NR. In some examples, it is proposed on how to indicate TA offset for uplink/downlink switching in NR. Some examples are given for the detail definition, where forward compatibility, frequency dependency, flexibility, message headroom etc. are considered.

[0010] In some examples, methods in a wireless communication device include determining a timing advance (TA) offset for uplink/downlink switching, wherein the TA offset is at least based on the time offset requirement for uplink/downlink switching in different scenarios used in communication between the wireless communication device and a network node and applying the determined TA offset in the uplink communication from the wireless communication device to the network node.

[0011] In some examples, methods in network node include determining a timing advance (TA) offset for uplink/downlink switching, wherein the TA offset is at least based on the time offset

requirement for uplink/downlink switching in different scenarios used in communication between the network node and a wireless communication device and sending the determined TA offset to the wireless communication device, wherein the TA offset is to be applied in the uplink communication from the wireless communication device to the network node.

[0012] In some examples, an apparatus may be configured to operate as a wireless communication device that includes at least one processor and a non-transitory computer readable medium coupled to the at least one processor. The non-transitory computer readable medium contains instructions executable by the at least one processor such that the at least one processor is configured to determine a timing advance (TA) offset for uplink/downlink switching. The TA offset is at least based on the time offset requirement for uplink/downlink switching in different scenarios used in communication between the wireless communication device and a network node. Method include applying the determined TA offset in the uplink communication from the wireless communication device to the network node.

[0013] In some examples, an apparatus configured to operate as a network node includes at least one processor and a non-transitory computer readable medium coupled to the at least one processor. The non-transitory computer readable medium contains instructions executable by the at least one processor, whereby the at least one processor is configured to determine a timing advance (TA) offset for uplink/downlink switching. The TA offset is at least based on the time offset requirement for uplink/downlink switching in different scenarios used in communication between the network node and a wireless communication device. The at least one processor is further configured to send the determined TA offset to the wireless communication device. The TA offset is to be applied in the uplink communication from the wireless communication device to the network node.

[0014] Some examples disclosed herein are directed to methods in a wireless communication device. Operations in such methods may include determining a timing advance (TA) offset for uplink/downlink switching, wherein the TA offset is based on a time offset requirement for uplink/downlink switching in different configurations used in communication between the wireless communication device and a network node, and applying the determined TA offset in an uplink communication from the wireless communication device to the network node.

[0015] In some examples, the wireless communication device includes a user equipment (UE).

[0016] Some examples provide that methods further include receiving a message including the TA offset from the network node. In some examples, applying the determined TA offset comprises applying the received TA offset.

[0017] In some examples, the message is a random access response (RAR) message. Some examples provide that the TA offset is included in a TA command (TAC). In some examples, the TA offset is predefined constant value, for a particular frequency band and a particular frame structure. Some examples provide that the particular frame structure comprises one of a plurality of duplex modes. In some examples, the TA offset takes two or three bits in the

message.

[0018] In some examples, applying the TA offset further includes applying a timing advance corresponding to a propagation delay between the wireless communication device and the network node, in addition to the TA offset. Some examples provide that the timing advance corresponding to the propagation delay is sent from the network node in a TA command in a RAR message.

[0019] In some examples, the TA offset value depends on the frequency band. Some examples provide that the TA offset has a first TA offset value for a first frequency band that is below a frequency threshold for a time division duplex and a second TA offset value for a second frequency band that is equal to or above the frequency threshold and that the first TA offset value is different than the second TA offset value. Some examples provide that the first TA offset value is greater than the second TA offset value. In some examples, for non-time division duplex (non-TDD), the TA offset is 0.

[0020] Some examples provide that the frequency threshold includes about 6GHz, the first TA offset includes about 20μs, and the second TA offset includes about 10μs. In some examples, the TA offset is independent of NR-LTE co-existence.

[0021] Some examples of the present disclosure are directed to methods in a network node. Operations corresponding to such methods include determining a timing advance (TA) offset for uplink/downlink switching, wherein the TA offset is based on a time offset requirement for uplink/downlink switching in different configurations used in communication between the network node and a wireless communication device, and sending the determined TA offset to the wireless communication device. In some examples, the TA offset corresponds to an uplink communication from the wireless communication device to the network node.

[0022] Some examples provide that the TA offset is sent in a random access response (RAR) message. In some examples, the TA offset is included in a TA command (TAC). The TA offset may take two or three bits in some example examples. Some examples include sending a timing advance corresponding to a propagation delay between the wireless communication device and the network node to the wireless communication device, in a TA command in a RAR message.

[0023] In some examples, the TA offset value depends on the frequency band. Some examples provide that the TA offset has a first TA offset value for a first frequency band that is below a frequency threshold for a time division duplex and a second TA offset value for a second frequency band that is equal to or above the frequency threshold, wherein the first TA offset value is different than the second TA offset value. In some examples, the first TA offset value is greater than the second TA offset value.

[0024] Some examples provide that the TA offset is 0 for non-time division duplex (non-TDD). In some examples, the frequency threshold is about 6GHz, the first TA offset is about 20μs,

and the second TA offset is about 10μs.

[0025] In some examples, the TA offset is predefined constant value, for a particular frequency band and a particular frame structure. In some examples, the TA offset is independent of NR-LTE co-existence.

[0026] Some examples of the present disclosure are directed to an apparatus that is configured to operate as a wireless communication device. The device includes at least one processor and a non-transitory computer readable medium coupled to the at least one processor, the non-transitory computer readable medium containing instructions executable by the at least one processor. The at least one processor is configured to perform operations of methods disclosed herein.

[0027] Some examples of the present disclosure are directed to a computer readable medium that includes computer readable code, which when run on an apparatus, causes the apparatus to perform operations corresponding to methods disclosed herein.

[0028] In further examples, there proposes a computer readable medium comprising computer readable code, which when run on an apparatus, causes the apparatus to perform any of the above methods.

[0029] With examples herein, uplink/downlink switching time for NR may be defined.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] The accompanying drawings, which are incorporated herein and form part of the specification, illustrate various embodiments of the present disclosure and, together with the description, further serve to explain the principles of the disclosure and to enable a person skilled in the pertinent art to make and use the embodiments disclosed herein. In the drawings, like reference numbers indicate identical or functionally similar elements, and in which:

Figure 1 shows the timing advance of the uplink transmission before the downlink transmission according to the prior art.

Figure 2 shows the timing advance of the uplink transmission before the downlink transmission in NR

Figure 3 shows a schematic diagram of an example wireless communication system, in which the embodiments can be implemented.

Figure 4 is a schematic flow chart showing a method in wireless communication device, according to the embodiments.

Figure 5 is a schematic flow chart showing a method in network node, according to the

embodiments.

Figure 6 is a schematic block diagram showing an example wireless communication device, according to the embodiments.

Figure 7 is a schematic block diagram showing an example network node, according to the embodiments.

Figure 8 is a schematic block diagram showing an apparatus, according to the embodiments.

Figure 9 is a block diagram illustrating elements of a UE configured to operate according to some embodiments disclosed herein.

Figure 10 is a block diagram illustrating elements of a network node according to some embodiments disclosed herein.

Figure 11 is a schematic block diagram illustrating a wireless network including some embodiments disclosed herein.

Figure 12 is a schematic block diagram illustrating some embodiments of a UE in accordance with various embodiments disclosed herein.

Figure 13 is a schematic block diagram illustrating a virtualization environment in which functions implemented by some embodiments disclosed herein may be virtualized.

Figure 14 is a schematic block diagram illustrating a communication system including a telecommunication network that includes an access network and a core network according to some embodiments disclosed herein.

Figure 15 is a schematic block diagram illustrating a UE, a base station and a host computer according to some embodiments disclosed herein.

Figure 16 is a block diagram illustrating operations of methods of operating a wireless communication device according to some embodiments disclosed herein.

Figure 17 is a block diagram illustrating operations of methods of operating a network node according to some embodiments disclosed herein.

DETAILED DESCRIPTION

[0031] Embodiments herein will be described in detail hereinafter with reference to the accompanying drawings, in which embodiments are shown. These embodiments herein may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein. The elements of the drawings are not necessarily to scale relative to each other.

[0032] Reference to "one embodiment" or "an embodiment" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, the appearances of the phrase "in one embodiment" appearing in various places throughout the specification are not necessarily all referring to the same embodiment.

[0033] Figure 3 shows a schematic diagram of an example wireless communication system 300, in which the embodiments can be implemented. In some embodiments, the wireless communication system 300 may include at least one wireless communication device 301 and at least one network node 302. However, the embodiments herein do not limit the number of the wireless communication device 301 and the network node 302.

[0034] In some embodiments, the wireless communication system 300 may be embodied as for example UE, device to device (D2D) UE, proximity capable UE (i.e., ProSe UE), machine type UE or UE capable of machine to machine (M2M) communication, Personal Digital Assistant (PDA), PAD, Tablet, mobile terminals, smart phone, laptop embedded equipped (LEE), laptop mounted equipment (LME), USB dongles, etc.

[0035] In some embodiments, the network node 302 may embodied as for example eNodeB (eNB), Base Station (BS), network controller, radio network controller (RNC), base station controller (BSC), relay, donor node controlling relay, base transceiver station (BTS), access point (AP), transmission points, transmission nodes, etc.

[0036] Embodiments herein, which will be described by referring to Figure 3, introduce TA offset in NR, and three example embodiments are given below. In each example embodiment, embodiments are also provided assuming for example around 20μs in maximum may be used for the TA offset value.

[0037] Some systems, such as those that may conform to 3GPP, include some working assumptions related to the initial TA command used for Random Access Response (RAR), including a maximum size of TA Command (TAC, Timing Advance Command) for RAR is 12 bits and that for the timing advance in RAR, the granularity may depend on the subcarrier spacing of the first uplink transmission after RAR (see the following table 1). Note that T_c = 1/(64*30.72*10^6) seconds. For example, Table 1 as provided below illustrates the granularity T_u of a 12 bit TA command:

Table 1. Granularity T_u of [12] bits TA command.

Subcarrier Spacing (kHz) of the first uplink transmission after RAR	Unit T_u
15	16*64 T_c
30	8*64 T_c
60	4*64 T_c

Subcarrier Spacing (kHz) of the first uplink transmission after RAR	Unit T_u
120	2*64 T_c

[0038] In some embodiments, a TA offset may be specified in 3GPP TS 38.211 similar to what has been done in 36.211 for LTE, but with different values, for example, for below 6GHz and above 6GHz frequency bands.

[0039] In some embodiments, a constant time may be defined for different frame structures and different frequency bands. Below is an example assuming the offset value is around 20μs for below 6GHz case and 10μs for above 6GHz case.

TA offset is
624*64 T_c: TDD in band below 6GHz
312*64 T_c: TDD in band above 6GHz
0: non-TDD case

[0040] In some embodiments, the TA offset for 6GHz frequency band can be set by referring the case of below 6GHz or the case of above 6GHz. For example, the TA offset for 6GHz frequency band can be set as 10μs or 312*64 T_c.

[0041] Note that, the embodiments do not limit to the above definition of TA offset. In some embodiments, the TA offset is at least based on the time offset requirement for uplink/downlink switching in different scenarios used in communication between the wireless communication device and a network node. The different scenarios may include but not be limited to different frame structures, different frequency band, coexisting with LTE, etc. For example, in some embodiments, the TA offset is predefined constant value, for a particular frequency band and a particular frame structure.

[0042] In some embodiments, the wireless communication device 301 can determine the TA offset by using embodiments described above and then applying the determined TA offset in the uplink communication from the wireless communication device 301 to the network node 302.

[0043] In some embodiments, when applying the TA offset, the wireless communication device 301 may also apply a timing advance TA corresponding to a propagation delay between the wireless communication device and the network node, in addition to the TA offset, wherein the timing advance TA corresponding to the propagation delay is sent from the network node in a TA command in a RAR message. That is, a timing advance of (TA + TA offset) is applied.

[0044] In some embodiments, the TA corresponding to the propagation delay is maintained by

the network node 302 through timing advance commands (TACs), i.e., timing alignment commands, sent to the wireless communication device 301 based on measurements on UL transmissions from that wireless communication device 301. For example, some embodiments provide that the network node 302 measures two-way propagation delay or round trip time for each wireless communication device 301 to determine the value of the TA required for that wireless communication device 301.

[0045] With the currently discussed example embodiments, the headroom of the message may be saved to transfer the TA command. As such, embodiments may not require any extra bits for transferring the TA offset, even though such embodiments may not be flexible.

[0046] In some further embodiments, one or more new parameters that are specific for the TA offset in NR RAR message may be defined. In some embodiments, a new TA offset parameter may be included in for example, the RAR message.

[0047] An example is the definition below with 2 bits:

TA offset (2 bits)
00: 0 T_c
01: 312*64 T_c
10: 624*64 T_c
11: reserved

[0048] Another example of such embodiments may support more values by including a definition as provided below with 3 bits:

TA offset (3 bits)
001: 312*64 T_c
010: 156*64 T_c
011: 78*64 T_c
100: 39*64 T_c
101: 20*64 T_c
110: 10*64 T_c
111: 0 T_c

[0049] In some embodiments, the frequency band definition in RAN4 specification may specify the minimum switching time that the UE may assume. Some embodiments provide that examples include 0 for non-TDD (such as FDD) band; 624*64 T_c: TDD in band below 6GHz; and/or 312*64 T_c: TDD in band above 6GHz.

[0050] In some embodiments, the TA offset for 6GHz frequency band can be set by referring the case of below 6GHz or the case of above 6GHz. For example, the TA offset for 6GHz frequency band can be set as 10μs or 312*64 T_C.

[0051] Note that, such embodiments may not limit to the above definition of TA offset. In some embodiments, the TA offset may be based, at least partially, on the time offset requirement for uplink/downlink switching in different scenarios used in communication between the wireless communication device and a network node. The different scenarios may include but are not limited to different frame structures, different frequency band, coexisting with LTE, etc.

[0052] In some embodiments, the wireless communication device 301 can determine the TA offset by using the TA offset received from the network node 302 (referring to above embodiments), and then apply the determined TA offset in the uplink communication from the wireless communication device 301 to the network node 302.

[0053] Accordingly, in some embodiments, the network node 302 may determine a timing advance (TA) offset for uplink/downlink switching, wherein the TA offset is at least based on the time offset requirement for uplink/downlink switching in different scenarios used in communication between the network node and a wireless communication device; and then send the determined TA offset to the wireless communication device in a message (such as RAR), wherein the TA offset is to be applied in the uplink communication from the wireless communication device to the network node.

[0054] Note that, the message carrying the TA offset is not limited to the RAR message. In some embodiments, the TA offset can be sent from the network node 302 to the wireless communication device 301 in any message and/or type thereof.

[0055] Note that the quantity of bits used by the TA offset is not limited to 2 or 3 bits. In some embodiments, the TA offset can use any number of bits.

[0056] In some embodiments, when applying the TA offset, the wireless communication device 301 may also apply a timing advance TA corresponding to a propagation delay between the wireless communication device and the network node, in addition to the TA offset. In some embodiments, the timing advance TA corresponding to the propagation delay may be sent from the network node in a TA command in a RAR message. In such embodiments a timing advance of (TA + TA offset) may be applied.

[0057] Accordingly, in some embodiments, the network node 302 may further send a timing advance corresponding to a propagation delay between the wireless communication device and the network node to the wireless communication device, in a TA command in a RAR message.

[0058] In some embodiments, the TA corresponding to the propagation delay may be

maintained by the network node 302 through timing advance commands (TACs). Examples may include timing alignment commands, sent to the wireless communication device 301 based on measurements on UL transmissions from that wireless communication device 301. For example, the network node 302 may measure two-way propagation delay or round trip time for each wireless communication device 301 to determine the value of the TA required for that wireless communication device 301.

[0059] Some embodiments described above may be more flexible and future proof. For example, embodiments may be forward compatible and independent from the estimated TA values due to propagation delay but may use one or more bits the transfer the TA offset.

[0060] In yet other embodiments, there includes the TA offset in the TA command in NR RAR message. For example, such embodiments may provide that the TA command contains both of the estimated TA values based on the uplink transmission and the TA offset for UL/DL switching.

[0061] Some systems, such as those that may conform to 3GPP, include identified msg3 Subcarrier Spacing (SCS). Such agreements may provide that NR supports RACH configuration in RMSI containing 1 bit to convey SCS of Msg3, in less than 6 GHz, subcarrier spacing of Msg3 can be either 15 or 30 kHz, and in greater that 6 GHz, subcarrier spacing of Msg3 can be either 60 or 120 kHz.

[0062] In such embodiments, since the TA offset will be merged into the TA command, the embodiments could use same granularity for different SCS as indicated in Table 1 above.

[0063] Some embodiments provide that the TA offset values may be defined in a manner consistent with the example values provided in Table 2, below. Note that T_u is defined in Table 1 for each SCS.

Table 2. TA_offset in TA command

Subcarrier Spacing (kHz) of the first uplink transmission after RAR	TA_offset
15kHz	39 T_u
30kHz	78 T_u
60kHz	78 T_u
120kHz	156 T_u

[0064] In some embodiments, the frequency band definition in RAN4 specification may specify the minimum switching time the UE may assume where the values could for example be 0 for non-TDD (such as FDD) band, 624*64 T_c: TDD in band below 6GHz, 312*64 T_c: TDD in band above 6GHz.

[0065] In some embodiments, the TA offset for 6GHz frequency band can be set by referring

the case of below 6GHz or the case of above 6GHz. For example, the TA offset for 6GHz frequency band can be set as 10μs or 312*64 T_c.

[0066] Such embodiments do not limit to the above definition of TA offset. For example, some embodiments provide that the TA offset is at least based on the time offset requirement for uplink/downlink switching in different scenarios used in communication between the wireless communication device and a network node. The different scenarios may include but are not limited to different frame structures, different frequency bands, and/or coexisting with LTE, among others.

[0067] In some embodiments, the wireless communication device 301 can determine the TA offset by using the TA offset in the TAC field of RAR message received from the network node 302, and the wireless communication device 301 can also determine a timing advance TA corresponding to a propagation delay between the wireless communication device and the network node by referring the above TAC field. Then, the wireless communication device 301 may apply the determined TA offset and TA corresponding to a propagation delay in the uplink communication from the wireless communication device 301 to the network node 302. In such embodiments, a timing advance of (TA + TA offset) is applied.

[0068] Accordingly, in some embodiments, the network node 302 may determine a timing advance (TA) offset for uplink/downlink switching. For example, the TA offset may be at least based on the time offset requirement for uplink/downlink switching in different scenarios used in communication between the network node and a wireless communication device. Some embodiments provide that the network node 302 may determine a timing advance corresponding to a propagation delay between the wireless communication device and the network node to the wireless communication device. Then, the network node 302 may merge the determined TA offset and the TA corresponding to a propagation delay into TAC field of RAR message, and then send it to the wireless communication device 301.

[0069] In some embodiments, the TA corresponding to the propagation delay is maintained by the network node 302 through timing advance commands (TACs), i.e., timing alignment commands, that may be sent to the wireless communication device 301 based on measurements on UL transmissions from that wireless communication device 301. For example, the network node 302 measures two-way propagation delay and/or round-trip time for each wireless communication device 301 to determine the value of the TA required for that wireless communication device 301.

[0070] Such embodiments may be more flexible and may save headroom of the message to transfer the TA command. Additionally, the TA command may be transparent to UE. Such embodiments may be based on the condition that the agreed number of TA command bits (e.g. 12 bits) is enough to transfer both the TA and the TA offset.

[0071] Reference is now made to Figure 4, which is a schematic flow chart showing a method 400 in wireless communication device 301, according to some embodiments.

[0072] The method 400 may begin with block 401, receiving timing advance command in RAR message from the network node 302. In some embodiments, the timing advance command may include timing advance (TA) offset and the timing advance corresponding to the propagation delay. In some other embodiments, the timing advance command may include only the timing advance corresponding to the propagation delay. In some embodiments, the wireless communication device 301 may receive the TA offset in any field in RAR message or in any other message sent from the network node 302. In some embodiments, the TA offset may take for example but not limit to two or three bits in the message.

[0073] In some embodiments, the TA corresponding to the propagation delay is maintained by the network node 302 through timing advance commands (TACs), i.e., timing alignment commands, sent to the wireless communication device 301 based on measurements on UL transmissions from that wireless communication device 301. For example, the network node 302 may measure two-way propagation delay or round-trip time for each wireless communication device 301 to determine the value of the TA required for that wireless communication device 301.

[0074] In some embodiments, the method 400 may proceed to block 402, the wireless communication device 301 may determine a timing advance (TA) offset for uplink/downlink switching. In some embodiments, the wireless communication device 301 may determine the TA offset itself. In some other embodiments, the wireless communication device 301 may determine the TA offset by using the TA offset received from the network node 302.

[0075] In some embodiments, the TA offset is at least based on the time offset requirement for uplink/downlink switching in different scenarios used in communication between the wireless communication device and a network node. The different scenarios can be for example but not limited to different frame structures, different frequency band, coexisting with LTE, etc.

[0076] For example, in some embodiments, there defines constant time for different frame structures and different frequency band. In some embodiments, for TDD, the TA offset value is around 20μs for below 6GHz case and 10μs for above 6GHz case. For non-TDD (such as FDD), the TA offset value is 0.

[0077] In some embodiments, the frequency band definition in a RAN4 specification would specify the minimum switching time that the UE may assume. Examples values may include 0 for non-TDD (such as FDD) band, 624*64 T_C: TDD in band below 6GHz, and/or 312*64 T_C: TDD in band above 6GHz.

[0078] In some embodiments, the TA offset for 6GHz frequency band can be set by referring the case of below 6GHz or the case of above 6GHz. For example, the TA offset for 6GHz frequency band can be set as 10μs or 312*64 T_C.

[0079] In some embodiments, the method 400 may proceed to block 403 in which the wireless

communication device 301 may apply the TA offset and the TA corresponding to the propagation delay, i.e., (TA + TA offset), in the uplink communication from the wireless communication device to the network node.

[0080] Reference is now made to Figure 5, which is a schematic flow chart showing a method 500 in network node 302, according to some embodiments.

[0081] The method 500 may begin with the operation of block 501, which is determining a timing advance (TA) offset for uplink/downlink switching. In some embodiments, the TA offset is to be applied in the uplink communication from the wireless communication device 301 to the network node 302. In some embodiments, the network node 302 may determine the TA offset at least based on the time offset requirement for uplink/downlink switching in different scenarios used in communication between the wireless communication device and a network node. The different scenarios may include, for example, but are not limited to different frame structures, different frequency band, coexisting with LTE, etc.

[0082] For example, in some embodiments, a constant time is defined for different frame structures and different frequency band. In one embodiment, for TDD, the TA offset value is around 20μs for below 6GHz case and 10μs for above 6GHz case. For non-TDD (such as FDD), the TA offset value is 0.

[0083] In one embodiment, the frequency band definition may be specified as the minimum switching time the UE may assume. Some embodiments provide the values may be, for example, 0 for non-TDD (such as FDD) band, 624*64 T_C: TDD in band below 6GHz, and/or 312*64 T_C: TDD in band above 6GHz.

[0084] In some embodiments, the TA offset for 6GHz frequency band can be determined by referring the case of below 6GHz or the case of above 6GHz. For example, the TA offset for 6GHz frequency band can be determined as 10μs or 312*64 T_C.

[0085] In some embodiments, the method 500 may perform operations of block 502, which include determining, by the network node 502, the timing advance TA corresponding to the propagation delay.

[0086] In some embodiments, the TA corresponding to the propagation delay is maintained by the network node 302 through timing advance commands (TACs) that are sent to the wireless communication device 301 based on measurements on UL transmissions from that wireless communication device 301. Examples of TACs may include timing alignment commands, among others. For example, the network node 302 may measure two-way propagation delay and/or round-trip time for each wireless communication device 301 to determine the value of the TA required for that wireless communication device 301.

[0087] In one embodiment, the method 500 may include operations of block 503, which include sending, by the network node 502, the determined TA offset to the wireless

communication device 301. In some embodiments, the determined TA offset and the timing advance corresponding to the propagation delay are merged into the Timing Advance (TA) command, and sent in the RAR message. In some other embodiments, the determined TA offset may be sent in any other message, and the timing advance command may include only the timing advance corresponding to the propagation delay. In yet further embodiments, the determined TA offset can be sent in any field in RAR message or in any other message to the wireless communication device. In some embodiments, the TA offset may use, for example, 2 or three bits, however, such examples are non-limiting as the TA offset may use more than three bits according to some embodiments.

[0088] Reference is now made to Figure 6, which is a schematic block diagram showing an example wireless communication device 301, according to some embodiments. In some embodiments, the wireless communication device 301 may include but is not limited to a receiving unit 601, a determining unit 602, and an applying unit 603. In some embodiments, the receiving unit 601, the determining unit 602, and the applying unit 603 can be configured to perform operations 410, 402, and 403, respectively, as discussed above regarding Figure 4.

[0089] In some embodiments, the receiving unit 601 may receive timing advance command in RAR message from the network node 302. In some embodiments, the timing advance command may include timing advance (TA) offset and the timing advance corresponding to the propagation delay. In some other embodiments, the timing advance command may include only the timing advance corresponding to the propagation delay. Some embodiments provide that the receiving unit 601 may receive the TA offset in any field in RAR message or in any other message sent from the network node 302. In some embodiments, the TA offset may use, for example, two or three bits in the message, however, such embodiments are non-limiting as the TA offset may use more than three bits in some embodiments.

[0090] In some embodiments, the TA corresponding to the propagation delay may be maintained by the network node 302 through timing advance commands (TACs), which may include timing alignment commands, that are sent to the wireless communication device 301 based on measurements on UL transmissions from that wireless communication device 301. For example, the network node 302 may measure two-way propagation delay and/or round-trip time for each wireless communication device 301 to determine the value of the TA required for that wireless communication device 301.

[0091] In some embodiments, the determining unit 602 may determine a timing advance (TA) offset for uplink/downlink switching. In some embodiments, the determining unit 602 may determine the TA offset itself. In some other embodiments, the determining unit 602 may determine the TA offset by using the TA offset received from the network node 302.

[0092] In some embodiments, the TA offset is at least based on the time offset requirement for uplink/downlink switching in different scenarios used in communication between the wireless communication device and a network node. The different scenarios can include, for example, but are not limited to different frame structures, different frequency band, coexisting with LTE,

etc.

[0093] For example, in some embodiments, a constant time may be defined for different frame structures and different frequency bands. In some embodiments, for TDD, the TA offset value is around 20μs for below 6GHz case and 10μs for above 6GHz case. For non-TDD (such as FDD), the TA offset value may be 0.

[0094] In some embodiments, the frequency band definition may include a specification regarding the minimum switching time the UE may assume. Some embodiments provide that examples of such embodiments include values of 0 for non-TDD (such as FDD) band, 624*64 T_C: TDD in bands below 6GHz, and312*64 T_C: TDD in bands above 6GHz.

[0095] In one embodiment, the TA offset for 6GHz frequency band can be set based on the case of below 6GHz or the case of above 6GHz. For example, some embodiments provide that the TA offset for 6GHz frequency band can be set as 10μs or 312*64 T_C.

[0096] In some embodiments, the applying unit 603 may apply the TA offset and the TA corresponding to the propagation delay, i.e., (TA + TA offset), in the uplink communication from the wireless communication device to the network node.

[0097] Note that, the receiving unit 601, determining unit 602, and applying unit 603 can implemented by a receiving circuity and/or module, a determining circuity and/or module, and an applying circuity and/or module respectively.

[0098] Reference is now made to Figure 7, which is a schematic block diagram showing an example network node 302, according to some embodiments. In some embodiments, the network node 302 may include a determining unit 701 and a sending unit 702. In some embodiments, the determining unit 701 and the sending unit 702 can be configured to perform operations described herein.

[0099] In some embodiments, the determining unit 701 may determine a timing advance (TA) offset for uplink/downlink switching, wherein the TA offset is to be applied in the uplink communication from the wireless communication device 301 to the network node 302. In one embodiment, the determining unit 701 may determine the TA offset at least based on the time offset requirement for uplink/downlink switching in different scenarios used in communication between the wireless communication device and a network node. The different scenarios may include but are not limited to different frame structures, different frequency band, coexisting with LTE, etc.

[0100] For example, in some embodiments, a constant time may be defined for different frame structures and different frequency bands. In some embodiments, for TDD, the TA offset value is around 20μs for below 6GHz case and 10μs for above 6GHz case. For non-TDD (such as FDD), the TA offset value may be 0.

[0101] In some embodiments, the frequency band definition may specify the minimum switching time that the UE may assume. Examples of corresponding TA offset values may include 0 for non-TDD (such as FDD) band, 624*64 T_C: TDD in bands below 6GHz, and/or 312*64 T_C: TDD in bands above 6GHz.

[0102] In one embodiment, the TA offset for 6GHz frequency band can be set by referring the case of below 6GHz or the case of above 6GHz. For example, the TA offset for 6GHz frequency band can be set as 10μs or 312*64 T_C.

[0103] In some embodiments, the determining unit 701 may determine the timing advance TA corresponding to the propagation delay.

[0104] In some embodiments, the TA corresponding to the propagation delay is maintained by the network node 302 through timing advance commands (TACs), such as timing alignment commands, which may be sent to the wireless communication device 301 based on measurements on UL transmissions from that wireless communication device 301. In some embodiments, the network node 302 measures two-way propagation delay or round trip time for each wireless communication device 301 to determine the value of the TA required for that wireless communication device 301.

[0105] In some embodiments, the sending unit 702 may send the determined TA offset to the wireless communication device 301. In some embodiments, the determined TA offset and the timing advance corresponding to the propagation delay may be merged into the Timing Advance (TA) command, and sent in the RAR message. In some other embodiments, the determined TA offset may be sent in any other message, and the timing advance command may include only the timing advance corresponding to the propagation delay. In yet further embodiments, the determined TA offset may be sent in any field in RAR message and/or in any other message to the wireless communication device. In some embodiments, the TA offset may take for example but not limit to two or three bits in the message.

[0106] Reference is now made to Figure 8, which is a schematic block diagram showing an apparatus 800, according to some embodiments. In some embodiments, the apparatus 800 can be configured as the above-mentioned apparatus, such as the wireless communication device 301 and/or the network node 302.

[0107] In some embodiments, the apparatus 800 may include but is not limited to at least one processor such as Central Processing Unit (CPU) 801, a computer-readable medium 802, and a memory 803. The memory 803 may include a volatile (e.g. Random Access Memory, RAM) and/or non-volatile memory (e.g. a hard disk or flash memory). In some embodiments, the computer-readable medium 802 may be configured to store a computer program and/or instructions, which, when executed by the processor 801, causes the processor 801 to carry out any of the above mentioned methods.

[0108] In some embodiments, the computer-readable medium 802 (such as non-transitory

computer readable medium) may be stored in the memory 803. In some embodiments, the computer program can be stored in a remote location for example computer program product 804, and accessible by the processor 801 via for example carrier 805.

[0109] The computer-readable medium 802 and/or the computer program product 804 may be distributed and/or stored on a removable computer-readable medium, e.g. diskette, CD (Compact Disk), DVD (Digital Video Disk), flash or similar removable memory media (e.g. compact flash, SD (secure digital), memory stick, mini SD card, MMC multimedia card, smart media), HD-DVD (High Definition DVD), or Blu-ray DVD, USB (Universal Serial Bus) based removable memory media, magnetic tape media, optical storage media, magneto-optical media, bubble memory, or distributed as a propagated signal via a network (e.g. Ethernet, ATM, ISDN, PSTN, X.25, Internet, Local Area Network (LAN), or similar networks capable of transporting data packets to the infrastructure node).

[0110] Figure 9 is a block diagram illustrating elements of a UE 900 (also referred to as a wireless terminal, a mobile equipment (ME), a wireless communication device, a wireless communication terminal, user equipment, a user equipment node/terminal/device, etc.) configured to operate according to embodiments disclosed herein. As shown, the UE 900 may include at least one antenna 907 (also referred to as antenna), and at least one transceiver circuit 901 (also referred to as transceiver) including a transmitter and a receiver configured to provide uplink and downlink radio communications with a base station or other radio transceiver element of a radio access network. The UE 900 may also include at least one processor circuit 903 (also referred to as processor) coupled to the transceiver 901, and at least one memory circuit 905 (also referred to as memory) coupled to the processor 903. The memory 905 may include computer readable program code that when executed by the processor 903 causes the processor 903 to perform operations according to embodiments disclosed herein for a UE. According to other embodiments, processor 903 may be defined to include memory so that a separate memory circuit is not required. The UE 900 may also include an interface (such as a user interface) coupled with processor 903.

[0111] As discussed herein, operations of the UE 900 may be performed by processor 903 and/or transceiver 901. Alternatively, or additionally, the UE 900 may include modules, e.g., software and/or circuitry, that performs respective operations (e.g., operations discussed herein with respect to example embodiments of UEs).

[0112] Figure 10 is a block diagram illustrating elements of a network node 1000 according to one or more embodiments disclosed herein. As shown, the network node 1000 may include at least one network interface circuit 1007 (also referred to as a network interface) configured to provide communications with other network nodes, such as one or more nodes of a access network, a core network, and/or another system node. The network node 1000 may also include at least one processor circuit 1003 (also referred to as a processor) coupled to the network interface 1007, and at least one memory circuit 1605 (also referred to as memory) coupled to the processor 1003. The memory 1005 may include computer readable program code that when executed by the processor 1003 causes the processor 1003 to perform

operations according to embodiments disclosed herein for a network node. According to other embodiments, processor 1003 may be defined to include memory so that a separate memory circuit is not required.

[0113] As discussed herein, operations of the network node 1000 may be performed by processor 1003 and/or network interface 1007. For example, processor 1003 may control network interface 1007 to send communications through network interface 1007 to one or more other network nodes and/or other system nodes, and/or to receive communications through network interface 1007 from one or more other network nodes and/or other system nodes. Alternatively, or additionally, the network node 1000 may include modules, e.g., circuitry, that performs respective operations (e.g., operations discussed herein with respect to example embodiments of network nodes).

[0114] In some embodiments, some or all of the operations described herein may be implemented as virtual components executed by one or more virtual machines implemented in one or more virtual environments hosted by one or more of network nodes. Further, in embodiments in which the virtual node is not a radio access node or does not require radio connectivity (e.g., a core network node), then the network node may be entirely virtualized.

[0115] The operations may be implemented by one or more applications (which may alternatively be called software instances, virtual appliances, network functions, virtual nodes, virtual network functions, etc.) operative to implement some of the features, functions, and/or benefits of some of the embodiments disclosed herein. Applications are run in a virtualization environment which provides hardware comprising processing circuitry and memory. Memory contains instructions executable by processing circuitry whereby application is operative to provide one or more of the features, benefits, and/or functions disclosed herein.

[0116] Example embodiments are described herein with reference to block diagrams and/or flowchart illustrations of computer-implemented methods, apparatus (systems and/or devices) and/or non-transitory computer program products. It is understood that a block of the block diagrams and/or flowchart illustrations, and combinations of blocks in the block diagrams and/or flowchart illustrations, can be implemented by computer program instructions that are performed by one or more computer circuits. These computer program instructions may be provided to a processor circuit of a general purpose computer circuit, special purpose computer circuit, and/or other programmable data processing circuit to produce a machine, such that the instructions, which execute via the processor of the computer and/or other programmable data processing apparatus, transform and control transistors, values stored in memory locations, and other hardware components within such circuitry to implement the functions/acts specified in the block diagrams and/or flowchart block or blocks, and thereby create means (functionality) and/or structure for implementing the functions/acts specified in the block diagrams and/or flowchart block(s).

[0117] These computer program instructions may also be stored in a tangible computer-readable 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 medium produce an article of manufacture including instructions which implement the functions/acts specified in the block diagrams and/or flowchart block or blocks. Accordingly, embodiments of the disclosed subject matter may be embodied in hardware and/or in software (including firmware, resident software, micro-code, etc.) that runs on a processor such as a digital signal processor, which may collectively be referred to as "circuitry," "a module" or variants thereof.

[0118] It should also be noted that in some alternate implementations, the functions/acts noted in the blocks may occur out of the order noted in the flowcharts. 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. Moreover, the functionality of a given block of the flowcharts and/or block diagrams may be separated into multiple blocks and/or the functionality of two or more blocks of the flowcharts and/or block diagrams may be at least partially integrated. Finally, other blocks may be added/inserted between the blocks that are illustrated, and/or blocks/operations may be omitted without departing from the scope of disclosed subject matter. Moreover, 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.

[0119] Many variations and modifications can be made to the embodiments without substantially departing from the principles of the disclosed subject matter. All such variations and modifications are intended to be included herein within the scope of the disclosed subject matter, as defined by the claims appended hereto. Accordingly, the above disclosed subject matter is to be considered illustrative, and not restrictive, and the appended examples of embodiments are intended to cover all such modifications, enhancements, and other embodiments, which fall within the scope of present inventive concepts, as defined by the claims appended hereto. Thus, to the maximum extent allowed by law, the scope of the disclosed subject matter is to be determined by the broadest permissible interpretation of the present disclosure including the following examples of embodiments and their equivalents, and shall not be restricted or limited by the foregoing detailed description.

Abbreviations

[0120]

3GPP
: third Generation Partnership Project

5G
: 5th-generation mobile communication technology

DL
: Downlink

FDD
: Frequency Division Duplex

LTE
: Long-Term Evolution

NR
: New Radio

OFDM
: Orthogonal Frequency Division Multiplexing

RAN
: Radio Access Network

RAR
: Random Access Response

SCS
: Sub-Carrier Spacing.

TA
: Timing Advance

TAC
: Timing Advance Command

TDD
: Time Division Duplex

UE
: User Equipment

UL
: Uplink

FURTHER DEFINITIONS AND EMBODIMENTS

[0121] In this disclosure a receiving node and a transmitting node is referred to. In the embodiments in one example the transmitting node can be a UE and the receiving node can be a network node. In another example the transmitting node can be a network node and the receiving node can be a UE. In yet another example the transmitting and receiving node can be involved in direct device to device communication, that is both can be considered UEs. Examples of device to device communication are proximity service (ProSe), ProSe direct discovery, ProSe direct communication, V2X (where X can denote V, I or P e.g. V2V, V2I, V2P etc) etc.

[0122] A network node is a more general term and can correspond to any type of radio network node or any network node, which communicates with a UE and/or with another network node. Examples of network nodes are NodeB, base station (BS), multi-standard radio (MSR) radio node such as MSR BS, eNodeB, gNodeB. MeNB, SeNB, network controller, radio

network controller (RNC), base station controller (BSC), road side unit (RSU), relay, donor node controlling relay, base transceiver station (BTS), access point (AP), transmission points, transmission nodes, RRU, RRH, nodes in distributed antenna system (DAS), core network node (e.g. MSC, MME etc), O&M, OSS, SON, positioning node (e.g. E-SMLC) etc.

[0123] Another example of a node could be user equipment, this is a non-limiting term user equipment (UE) and it refers to any type of wireless device communicating with a network node and/or with another UE in a cellular or mobile communication system. Examples of UE are target device, device to device (D2D) UE, V2X UE, ProSe UE, machine type UE or UE capable of machine to machine (M2M) communication, PDA, iPAD, Tablet, mobile terminals, smart phone, laptop embedded equipped (LEE), laptop mounted equipment (LME), USB dongles etc.

[0124] The term radio access technology, or RAT, may refer to any RAT e.g. UTRA, E-UTRA, narrow band internet of things (NB-IoT), WiFi, Bluetooth, next generation RAT (NR), 4G, 5G, etc. Any of the first and the second nodes may be capable of supporting a single or multiple RATs.The term signal used herein can be any physical signal or physical channel. Examples of downlink physical signals are reference signal such as PSS, SSS, CRS, PRS, CSI-RS, DMRS, NRS, NPSS, NSSS, SS, MBSFN RS etc. Examples of uplink physical signals are reference signal such as SRS, DMRS etc. The term physical channel (e.g., in the context of channel reception) used herein is also called as 'channel. The physical channel carries higher layer information (e.g. RRC, logical control channel etc). Examples of downlink physical channels are PBCH, NPBCH, PDCCH, PDSCH, sPDSCH, MPDCCH, NPDCCH, NPDSCH, E-PDCCH etc. Examples of uplink physical channels are sPUCCH. sPUSCH, PUSCH, PUCCH, NPUSCH, PRACH, NPRACH etc.

[0125] The term time resource used herein may correspond to any type of physical resource or radio resource expressed in terms of length of time and/or frequency. Signals are transmitted or received by a radio node over a time resource. Examples of time resources are: symbol, time slot, subframe, radio frame, TTI, interleaving time, etc.

[0126] Although the subject matter described herein may be implemented in any appropriate type of system using any suitable components, the embodiments disclosed herein are described in relation to a wireless network, such as the example wireless network illustrated in Figure 11. For simplicity, the wireless network of Figure 11 only depicts network 1106, network nodes 1160 and 1160b, and WDs 1110, 1110b, and 111110c. In practice, a wireless network may further include any additional elements suitable to support communication between wireless devices or between a wireless device and another communication device, such as a landline telephone, a service provider, or any other network node or end device. Of the illustrated components, network node 111 160 and wireless device (WD) 1110 are depicted with additional detail. The wireless network may provide communication and other types of services to one or more wireless devices to facilitate the wireless devices' access to and/or use of the services provided by, or via, the wireless network.

[0127] The wireless network may comprise and/or interface with any type of communication,

telecommunication, data, cellular, and/or radio network or other similar type of system. In some embodiments, the wireless network may be configured to operate according to specific standards or other types of predefined rules or procedures. Thus, particular embodiments of the wireless network may implement communication standards, such as Global System for Mobile Communications (GSM), Universal Mobile Telecommunications System (UMTS), Long Term Evolution (LTE), and/or other suitable 2G, 3G, 4G, or 5G standards; wireless local area network (WLAN) standards, such as the IEEE 802.11 standards; and/or any other appropriate wireless communication standard, such as the Worldwide Interoperability for Microwave Access (WiMax), Bluetooth, Z-Wave and/or ZigBee standards.

[0128] Network 1106 may comprise one or more backhaul networks, core networks, IP networks, public switched telephone networks (PSTNs), packet data networks, optical networks, wide-area networks (WANs), local area networks (LANs), wireless local area networks (WLANs), wired networks, wireless networks, metropolitan area networks, and other networks to enable communication between devices.

[0129] Network node 1160 and WD 1110 comprise various components described in more detail below. These components work together in order to provide network node and/or wireless device functionality, such as providing wireless connections in a wireless network. In different embodiments, the wireless network may comprise any number of wired or wireless networks, network nodes, base stations, controllers, wireless devices, relay stations, and/or any other components or systems that may facilitate or participate in the communication of data and/or signals whether via wired or wireless connections.

[0130] As used herein, network node refers to equipment capable, configured, arranged and/or operable to communicate directly or indirectly with a wireless device and/or with other network nodes or equipment in the wireless network to enable and/or provide wireless access to the wireless device and/or to perform other functions (e.g., administration) in the wireless network. Examples of network nodes include, but are not limited to, access points (APs) (e.g., radio access points), base stations (BSs) (e.g., radio base stations, Node Bs, evolved Node Bs (eNBs) and NR NodeBs (gNBs)). Base stations may be categorized based on the amount of coverage they provide (or, stated differently, their transmit power level) and may then also be referred to as femto base stations, pico base stations, micro base stations, or macro base stations. A base station may be a relay node or a relay donor node controlling a relay. A network node may also include one or more (or all) parts of a distributed radio base station such as centralized digital units and/or remote radio units (RRUs), sometimes referred to as Remote Radio Heads (RRHs). Such remote radio units may or may not be integrated with an antenna as an antenna integrated radio. Parts of a distributed radio base station may also be referred to as nodes in a distributed antenna system (DAS). Yet further examples of network nodes include multi-standard radio (MSR) equipment such as MSR BSs, network controllers such as radio network controllers (RNCs) or base station controllers (BSCs), base transceiver stations (BTSs), transmission points, transmission nodes, multi-cell/multicast coordination entities (MCEs), core network nodes (e.g., MSCs, MMEs), O&M nodes, OSS nodes, SON nodes, positioning nodes (e.g., E-SMLCs), and/or MDTs. As another example, a network node

may be a virtual network node as described in more detail below. More generally, however, network nodes may represent any suitable device (or group of devices) capable, configured, arranged, and/or operable to enable and/or provide a wireless device with access to the wireless network or to provide some service to a wireless device that has accessed the wireless network.

[0131] In Figure 11, network node 1160 includes processing circuitry 1170, device readable medium 1180, interface 1190, auxiliary equipment 1184, power source 1186, power circuitry 1187, and antenna 1162. Although network node 1160 illustrated in the example wireless network of Figure 11 may represent a device that includes the illustrated combination of hardware components, other embodiments may comprise network nodes with different combinations of components. It is to be understood that a network node comprises any suitable combination of hardware and/or software needed to perform the tasks, features, functions and methods disclosed herein. Moreover, while the components of network node 1160 are depicted as single boxes located within a larger box, or nested within multiple boxes, in practice, a network node may comprise multiple different physical components that make up a single illustrated component (e.g., device readable medium 1180 may comprise multiple separate hard drives as well as multiple RAM modules).

[0132] Similarly, network node 1160 may be composed of multiple physically separate components (e.g., a NodeB component and a RNC component, or a BTS component and a BSC component, etc.), which may each have their own respective components. In certain scenarios in which network node 1160 comprises multiple separate components (e.g., BTS and BSC components), one or more of the separate components may be shared among several network nodes. For example, a single RNC may control multiple NodeB's. In such a scenario, each unique NodeB and RNC pair, may in some instances be considered a single separate network node. In some embodiments, network node 1160 may be configured to support multiple radio access technologies (RATs). In such embodiments, some components may be duplicated (e.g., separate device readable medium 1180 for the different RATs) and some components may be reused (e.g., the same antenna 1162 may be shared by the RATs). Network node 1160 may also include multiple sets of the various illustrated components for different wireless technologies integrated into network node 1160, such as, for example, GSM, WCDMA, LTE, NR, WiFi, or Bluetooth wireless technologies. These wireless technologies may be integrated into the same or different chip or set of chips and other components within network node 1160.

[0133] Processing circuitry 1170 is configured to perform any determining, calculating, or similar operations (e.g., certain obtaining operations) described herein as being provided by a network node. These operations performed by processing circuitry 1170 may include processing information obtained by processing circuitry 1170 by, for example, converting the obtained information into other information, comparing the obtained information or converted information to information stored in the network node, and/or performing one or more operations based on the obtained information or converted information, and as a result of said processing making a determination.

[0134] Processing circuitry 1170 may comprise a combination of one or more of a microprocessor, controller, microcontroller, central processing unit, digital signal processor, application-specific integrated circuit, field programmable gate array, or any other suitable computing device, resource, or combination of hardware, software and/or encoded logic operable to provide, either alone or in conjunction with other network node 1160 components, such as device readable medium 1180, network node 1160 functionality. For example, processing circuitry 1170 may execute instructions stored in device readable medium 1180 or in memory within processing circuitry 1170. Such functionality may include providing any of the various wireless features, functions, or benefits discussed herein. In some embodiments, processing circuitry 1170 may include a system on a chip (SOC).

[0135] In some embodiments, processing circuitry 1170 may include one or more of radio frequency (RF) transceiver circuitry 1172 and baseband processing circuitry 1174. In some embodiments, radio frequency (RF) transceiver circuitry 1172 and baseband processing circuitry 1174 may be on separate chips (or sets of chips), boards, or units, such as radio units and digital units. In alternative embodiments, part or all of RF transceiver circuitry 1172 and baseband processing circuitry 1174 may be on the same chip or set of chips, boards, or units.

[0136] In certain embodiments, some or all of the functionality described herein as being provided by a network node, base station, eNB or other such network device may be performed by processing circuitry 1170 executing instructions stored on device readable medium 1180 or memory within processing circuitry 1170. In alternative embodiments, some or all of the functionality may be provided by processing circuitry 1170 without executing instructions stored on a separate or discrete device readable medium, such as in a hard-wired manner. In any of those embodiments, whether executing instructions stored on a device readable storage medium or not, processing circuitry 1170 can be configured to perform the described functionality. The benefits provided by such functionality are not limited to processing circuitry 1170 alone or to other components of network node 1160, but are enjoyed by network node 1160 as a whole, and/or by end users and the wireless network generally.

[0137] Device readable medium 1180 may comprise any form of volatile or non-volatile computer readable memory including, without limitation, persistent storage, solid-state memory, remotely mounted memory, magnetic media, optical media, random access memory (RAM), read-only memory (ROM), mass storage media (for example, a hard disk), removable storage media (for example, a flash drive, a Compact Disk (CD) or a Digital Video Disk (DVD)), and/or any other volatile or non-volatile, non-transitory device readable and/or computer-executable memory devices that store information, data, and/or instructions that may be used by processing circuitry 1170. Device readable medium 1180 may store any suitable instructions, data or information, including a computer program, software, an application including one or more of logic, rules, code, tables, etc. and/or other instructions capable of being executed by processing circuitry 1170 and, utilized by network node 1160. Device readable medium 1180 may be used to store any calculations made by processing circuitry 1170 and/or any data received via interface 1190. In some embodiments, processing circuitry

1170 and device readable medium 1180 may be considered to be integrated.

[0138] Interface 1190 is used in the wired or wireless communication of signaling and/or data between network node 1160, network 1106, and/or WDs 1110. As illustrated, interface 1190 comprises port(s)/terminal(s) 1194 to send and receive data, for example to and from network 1106 over a wired connection. Interface 1190 also includes radio front end circuitry 1192 that may be coupled to, or in certain embodiments a part of, antenna 1162. Radio front end circuitry 1192 comprises filters 1198 and amplifiers 1196. Radio front end circuitry 1192 may be connected to antenna 1162 and processing circuitry 1170. Radio front end circuitry may be configured to condition signals communicated between antenna 1162 and processing circuitry 1170. Radio front end circuitry 1192 may receive digital data that is to be sent out to other network nodes or WDs via a wireless connection. Radio front end circuitry 1192 may convert the digital data into a radio signal having the appropriate channel and bandwidth parameters using a combination of filters 1198 and/or amplifiers 1196. The radio signal may then be transmitted via antenna 1162. Similarly, when receiving data, antenna 1162 may collect radio signals which are then converted into digital data by radio front end circuitry 1192. The digital data may be passed to processing circuitry 1170. In other embodiments, the interface may comprise different components and/or different combinations of components.

[0139] In certain alternative embodiments, network node 1160 may not include separate radio front end circuitry 1192, instead, processing circuitry 1170 may comprise radio front end circuitry and may be connected to antenna 1162 without separate radio front end circuitry 1192. Similarly, in some embodiments, all or some of RF transceiver circuitry 1172 may be considered a part of interface 1190. In still other embodiments, interface 1190 may include one or more ports or terminals 1194, radio front end circuitry 1192, and RF transceiver circuitry 1172, as part of a radio unit (not shown), and interface 1190 may communicate with baseband processing circuitry 1174, which is part of a digital unit (not shown).

[0140] Antenna 1162 may include one or more antennas, or antenna arrays, configured to send and/or receive wireless signals. Antenna 1162 may be coupled to radio front end circuitry 1190 and may be any type of antenna capable of transmitting and receiving data and/or signals wirelessly. In some embodiments, antenna 1162 may comprise one or more omni-directional, sector or panel antennas operable to transmit/receive radio signals between, for example, 2 GHz and 66 GHz. An omni-directional antenna may be used to transmit/receive radio signals in any direction, a sector antenna may be used to transmit/receive radio signals from devices within a particular area, and a panel antenna may be a line of sight antenna used to transmit/receive radio signals in a relatively straight line. In some instances, the use of more than one antenna may be referred to as MIMO. In certain embodiments, antenna 1162 may be separate from network node 1160 and may be connectable to network node 1160 through an interface or port.

[0141] Antenna 1162, interface 1190, and/or processing circuitry 1170 may be configured to perform any receiving operations and/or certain obtaining operations described herein as being performed by a network node. Any information, data and/or signals may be received

from a wireless device, another network node and/or any other network equipment. Similarly, antenna 1162, interface 1190, and/or processing circuitry 1170 may be configured to perform any transmitting operations described herein as being performed by a network node. Any information, data and/or signals may be transmitted to a wireless device, another network node and/or any other network equipment.

[0142] Power circuitry 1187 may comprise, or be coupled to, power management circuitry and is configured to supply the components of network node 1160 with power for performing the functionality described herein. Power circuitry 1187 may receive power from power source 1186. Power source 1186 and/or power circuitry 1187 may be configured to provide power to the various components of network node 1160 in a form suitable for the respective components (e.g., at a voltage and current level needed for each respective component). Power source 1186 may either be included in, or external to, power circuitry 1187 and/or network node 1160. For example, network node 1160 may be connectable to an external power source (e.g., an electricity outlet) via an input circuitry or interface such as an electrical cable, whereby the external power source supplies power to power circuitry 1187. As a further example, power source 1186 may comprise a source of power in the form of a battery or battery pack which is connected to, or integrated in, power circuitry 1187. The battery may provide backup power should the external power source fail. Other types of power sources, such as photovoltaic devices, may also be used.

[0143] Alternative embodiments of network node 1160 may include additional components beyond those shown in Figure 11 that may be responsible for providing certain aspects of the network node's functionality, including any of the functionality described herein and/or any functionality necessary to support the subject matter described herein. For example, network node 1160 may include user interface equipment to allow input of information into network node 1160 and to allow output of information from network node 1160. This may allow a user to perform diagnostic, maintenance, repair, and other administrative functions for network node 1160.

[0144] As used herein, wireless device (WD) refers to a device capable, configured, arranged and/or operable to communicate wirelessly with network nodes and/or other wireless devices. Unless otherwise noted, the term WD may be used interchangeably herein with user equipment (UE) and mobile equipment (ME). Communicating wirelessly may involve transmitting and/or receiving wireless signals using electromagnetic waves, radio waves, infrared waves, and/or other types of signals suitable for conveying information through air. In some embodiments, a WD may be configured to transmit and/or receive information without direct human interaction. For instance, a WD may be designed to transmit information to a network on a predetermined schedule, when triggered by an internal or external event, or in response to requests from the network. Examples of a WD include, but are not limited to, a smart phone, a mobile phone, a cell phone, a voice over IP (VoIP) phone, a wireless local loop phone, a desktop computer, a personal digital assistant (PDA), a wireless cameras, a gaming console or device, a music storage device, a playback appliance, a wearable terminal device, a wireless endpoint, a mobile station, a tablet, a laptop, a laptop-embedded equipment (LEE), a

laptop-mounted equipment (LME), a smart device, a wireless customer-premise equipment (CPE). a vehicle-mounted wireless terminal device, etc. A WD may support device-to-device (D2D) communication, for example by implementing a 3GPP standard for sidelink communication, vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-everything (V2X) and may in this case be referred to as a D2D communication device. As yet another specific example, in an Internet of Things (IoT) scenario, a WD may represent a machine or other device that performs monitoring and/or measurements, and transmits the results of such monitoring and/or measurements to another WD and/or a network node. The WD may in this case be a machine-to-machine (M2M) device, which may in a 3GPP context be referred to as an MTC device. As one particular example, the WD may be a UE implementing the 3GPP narrow band internet of things (NB-IoT) standard. Particular examples of such machines or devices are sensors, metering devices such as power meters, industrial machinery, or home or personal appliances (e.g. refrigerators, televisions, etc.) personal wearables (e.g., watches, fitness trackers, etc.). In other scenarios, a WD may represent a vehicle or other equipment that is capable of monitoring and/or reporting on its operational status or other functions associated with its operation. A WD as described above may represent the endpoint of a wireless connection, in which case the device may be referred to as a wireless terminal. Furthermore, a WD as described above may be mobile, in which case it may also be referred to as a mobile device or a mobile terminal.

[0145] As illustrated, wireless device 1110 includes antenna 1111, interface 1114, processing circuitry 1120, device readable medium 1130, user interface equipment 1132, auxiliary equipment 1134, power source 1136 and power circuitry 1137. WD 1110 may include multiple sets of one or more of the illustrated components for different wireless technologies supported by WD 1110, such as, for example, GSM, WCDMA, LTE, NR, WiFi, WiMAX, or Bluetooth wireless technologies, just to mention a few. These wireless technologies may be integrated into the same or different chips or set of chips as other components within WD 1110.

[0146] Antenna 1111 may include one or more antennas or antenna arrays, configured to send and/or receive wireless signals, and is connected to interface 1114. In certain alternative embodiments, antenna 1111 may be separate from WD 1110 and be connectable to WD 1110 through an interface or port. Antenna 1111, interface 1114, and/or processing circuitry 1120 may be configured to perform any receiving or transmitting operations described herein as being performed by a WD. Any information, data and/or signals may be received from a network node and/or another WD. In some embodiments, radio front end circuitry and/or antenna 1111 may be considered an interface.

[0147] As illustrated, interface 1114 comprises radio front end circuitry 1112 and antenna 1111. Radio front end circuitry 1112 comprise one or more filters 1118 and amplifiers 1116. Radio front end circuitry 1114 is connected to antenna 1111 and processing circuitry 1120, and is configured to condition signals communicated between antenna 1111 and processing circuitry 1120. Radio front end circuitry 1112 may be coupled to or a part of antenna 1111. In some embodiments, WD 1110 may not include separate radio front end circuitry 1112; rather, processing circuitry 1120 may comprise radio front end circuitry and may be connected to

antenna 1111. Similarly, in some embodiments, some or all of RF transceiver circuitry 1122 may be considered a part of interface 1114. Radio front end circuitry 1112 may receive digital data that is to be sent out to other network nodes or WDs via a wireless connection. Radio front end circuitry 1112 may convert the digital data into a radio signal having the appropriate channel and bandwidth parameters using a combination of filters 1118 and/or amplifiers 1116. The radio signal may then be transmitted via antenna 1111. Similarly, when receiving data, antenna 1111 may collect radio signals which are then converted into digital data by radio front end circuitry 1112. The digital data may be passed to processing circuitry 1120. In other embodiments, the interface may comprise different components and/or different combinations of components.

[0148] Processing circuitry 1120 may comprise a combination of one or more of a microprocessor, controller, microcontroller, central processing unit, digital signal processor, application-specific integrated circuit, field programmable gate array, or any other suitable computing device, resource, or combination of hardware, software, and/or encoded logic operable to provide, either alone or in conjunction with other WD 1110 components, such as device readable medium 1130, WD 1110 functionality. Such functionality may include providing any of the various wireless features or benefits discussed herein. For example, processing circuitry 1120 may execute instructions stored in device readable medium 1130 or in memory within processing circuitry 1120 to provide the functionality disclosed herein.

[0149] As illustrated, processing circuitry 1120 includes one or more of RF transceiver circuitry 1122, baseband processing circuitry 1124, and application processing circuitry 1126. In other embodiments, the processing circuitry may comprise different components and/or different combinations of components. In certain embodiments processing circuitry 1120 of WD 1110 may comprise a SOC. In some embodiments, RF transceiver circuitry 1122, baseband processing circuitry 1124, and application processing circuitry 1126 may be on separate chips or sets of chips. In alternative embodiments, part or all of baseband processing circuitry 1124 and application processing circuitry 1126 may be combined into one chip or set of chips, and RF transceiver circuitry 1122 may be on a separate chip or set of chips. In still alternative embodiments, part or all of RF transceiver circuitry 1122 and baseband processing circuitry 1124 may be on the same chip or set of chips, and application processing circuitry 1126 may be on a separate chip or set of chips. In yet other alternative embodiments, part or all of RF transceiver circuitry 1122, baseband processing circuitry 1124, and application processing circuitry 1126 may be combined in the same chip or set of chips. In some embodiments, RF transceiver circuitry 1122 may be a part of interface 1114. RF transceiver circuitry 1122 may condition RF signals for processing circuitry 1120.

[0150] In certain embodiments, some or all of the functionality described herein as being performed by a WD may be provided by processing circuitry 1120 executing instructions stored on device readable medium 1130, which in certain embodiments may be a computer-readable storage medium. In alternative embodiments, some or all of the functionality may be provided by processing circuitry 1120 without executing instructions stored on a separate or discrete device readable storage medium, such as in a hard-wired manner. In any of those particular

embodiments, whether executing instructions stored on a device readable storage medium or not, processing circuitry 1120 can be configured to perform the described functionality. The benefits provided by such functionality are not limited to processing circuitry 1120 alone or to other components of WD 1110, but are enjoyed by WD 1110 as a whole, and/or by end users and the wireless network generally.

[0151] Processing circuitry 1120 may be configured to perform any determining, calculating, or similar operations (e.g., certain obtaining operations) described herein as being performed by a WD. These operations, as performed by processing circuitry 1120, may include processing information obtained by processing circuitry 1120 by, for example, converting the obtained information into other information, comparing the obtained information or converted information to information stored by WD 1110, and/or performing one or more operations based on the obtained information or converted information, and as a result of said processing making a determination.

[0152] Device readable medium 1130 may be operable to store a computer program, software, an application including one or more of logic, rules, code, tables, etc. and/or other instructions capable of being executed by processing circuitry 1120. Device readable medium 1130 may include computer memory (e.g., Random Access Memory (RAM) or Read Only Memory (ROM)), mass storage media (e.g., a hard disk), removable storage media (e.g., a Compact Disk (CD) or a Digital Video Disk (DVD)), and/or any other volatile or non-volatile, non-transitory device readable and/or computer executable memory devices that store information, data, and/or instructions that may be used by processing circuitry 1120. In some embodiments, processing circuitry 1120 and device readable medium 1130 may be considered to be integrated.

[0153] User interface equipment 1132 may provide components that allow for a human user to interact with WD 1110. Such interaction may be of many forms, such as visual, audial, tactile, etc. User interface equipment 1132 may be operable to produce output to the user and to allow the user to provide input to WD 1110. The type of interaction may vary depending on the type of user interface equipment 1132 installed in WD 1110. For example, if WD 1110 is a smart phone, the interaction may be via a touch screen; if WD 1110 is a smart meter, the interaction may be through a screen that provides usage (e.g., the number of gallons used) or a speaker that provides an audible alert (e.g., if smoke is detected). User interface equipment 1132 may include input interfaces, devices and circuits, and output interfaces, devices and circuits. User interface equipment 1132 is configured to allow input of information into WD 1110, and is connected to processing circuitry 1120 to allow processing circuitry 1120 to process the input information. User interface equipment 1132 may include, for example, a microphone, a proximity or other sensor, keys/buttons, a touch display, one or more cameras, a USB port, or other input circuitry. User interface equipment 1132 is also configured to allow output of information from WD 1110, and to allow processing circuitry 1120 to output information from WD 1110. User interface equipment 1132 may include, for example, a speaker, a display, vibrating circuitry, a USB port, a headphone interface, or other output circuitry. Using one or more input and output interfaces, devices, and circuits, of user interface equipment 1132, WD

1110 may communicate with end users and/or the wireless network, and allow them to benefit from the functionality described herein.

[0154] Auxiliary equipment 1134 is operable to provide more specific functionality which may not be generally performed by WDs. This may comprise specialized sensors for doing measurements for various purposes, interfaces for additional types of communication such as wired communications etc. The inclusion and type of components of auxiliary equipment 1134 may vary depending on the embodiment and/or scenario.

[0155] Power source 1136 may, in some embodiments, be in the form of a battery or battery pack. Other types of power sources, such as an external power source (e.g., an electricity outlet), photovoltaic devices or power cells, may also be used. WD 1110 may further comprise power circuitry 1137 for delivering power from power source 1136 to the various parts of WD 1110 which need power from power source 1136 to carry out any functionality described or indicated herein. Power circuitry 1137 may in certain embodiments comprise power management circuitry. Power circuitry 1137 may additionally or alternatively be operable to receive power from an external power source; in which case WD 1110 may be connectable to the external power source (such as an electricity outlet) via input circuitry or an interface such as an electrical power cable. Power circuitry 1137 may also in certain embodiments be operable to deliver power from an external power source to power source 1136. This may be, for example, for the charging of power source 1136. Power circuitry 1137 may perform any formatting, converting, or other modification to the power from power source 1136 to make the power suitable for the respective components of WD 1110 to which power is supplied.

[0156] Figure 12 illustrates one embodiment of a UE in accordance with various aspects described herein. As used herein, a user equipment or UE may not necessarily have a user in the sense of a human user who owns and/or operates the relevant device. Instead, a UE may represent a device that is intended for sale to, or operation by, a human user but which may not, or which may not initially, be associated with a specific human user (e.g., a smart sprinkler controller). Alternatively, a UE may represent a device that is not intended for sale to, or operation by, an end user but which may be associated with or operated for the benefit of a user (e.g., a smart power meter). UE 12200 may be any UE identified by the 3rd Generation Partnership Project (3GPP), including a NB-IoT UE, a machine type communication (MTC) UE, and/or an enhanced MTC (eMTC) UE. UE 1200, as illustrated in Figure 12, is one example of a WD configured for communication in accordance with one or more communication standards promulgated by the 3rd Generation Partnership Project (3GPP), such as 3GPP's GSM, UMTS, LTE, and/or 5G standards. As mentioned previously, the term WD and UE may be used interchangeable. Accordingly, although Figure 12 is a UE, the components discussed herein are equally applicable to a WD, and vice-versa.

[0157] In Figure 12, UE 1200 includes processing circuitry 1201 that is operatively coupled to input/output interface 1205, radio frequency (RF) interface 1209, network connection interface 1211, memory 1215 including random access memory (RAM) 1217, read-only memory (ROM) 1219, and storage medium 1221 or the like, communication subsystem 1231, power source

1233, and/or any other component, or any combination thereof. Storage medium 1221 includes operating system 1223, application program 1225, and data 1227. In other embodiments, storage medium 1221 may include other similar types of information. Certain UEs may utilize all of the components shown in Figure 12, or only a subset of the components. The level of integration between the components may vary from one UE to another UE. Further, certain UEs may contain multiple instances of a component, such as multiple processors, memories, transceivers, transmitters, receivers, etc.

[0158] In Figure 12, processing circuitry 1201 may be configured to process computer instructions and data. Processing circuitry 1201 may be configured to implement any sequential state machine operative to execute machine instructions stored as machine-readable computer programs in the memory, such as one or more hardware-implemented state machines (e.g., in discrete logic, FPGA, ASIC, etc.); programmable logic together with appropriate firmware; one or more stored program, general-purpose processors, such as a microprocessor or Digital Signal Processor (DSP), together with appropriate software; or any combination of the above. For example, the processing circuitry 1201 may include two central processing units (CPUs). Data may be information in a form suitable for use by a computer.

[0159] In the depicted embodiment, input/output interface 1205 may be configured to provide a communication interface to an input device, output device, or input and output device. UE 1200 may be configured to use an output device via input/output interface 1205. An output device may use the same type of interface port as an input device. For example, a USB port may be used to provide input to and output from UE 1200. The output device may be a speaker, a sound card, a video card, a display, a monitor, a printer, an actuator, an emitter, a smartcard, another output device, or any combination thereof. UE 1200 may be configured to use an input device via input/output interface 1205 to allow a user to capture information into UE 1200. The input device may include a touch-sensitive or presence-sensitive display, a camera (e.g., a digital camera, a digital video camera, a web camera, etc.), a microphone, a sensor, a mouse, a trackball, a directional pad, a trackpad, a scroll wheel, a smartcard, and the like. The presence-sensitive display may include a capacitive or resistive touch sensor to sense input from a user. A sensor may be, for instance, an accelerometer, a gyroscope, a tilt sensor, a force sensor, a magnetometer, an optical sensor, a proximity sensor, another like sensor, or any combination thereof. For example, the input device may be an accelerometer, a magnetometer, a digital camera, a microphone, and an optical sensor.

[0160] In Figure 12, RF interface 1209 may be configured to provide a communication interface to RF components such as a transmitter, a receiver, and an antenna. Network connection interface 1211 may be configured to provide a communication interface to network 1243a. Network 1243a may encompass wired and/or wireless networks such as a local-area network (LAN), a wide-area network (WAN), a computer network, a wireless network, a telecommunications network, another like network or any combination thereof. For example, network 1243a may comprise a Wi-Fi network. Network connection interface 1211 may be configured to include a receiver and a transmitter interface used to communicate with one or more other devices over a communication network according to one or more communication

protocols, such as Ethernet, TCP/IP, SONET, ATM, or the like. Network connection interface 1211 may implement receiver and transmitter functionality appropriate to the communication network links (e.g., optical, electrical, and the like). The transmitter and receiver functions may share circuit components, software or firmware, or alternatively may be implemented separately.

[0161] RAM 1217 may be configured to interface via bus 1202 to processing circuitry 1201 to provide storage or caching of data or computer instructions during the execution of software programs such as the operating system, application programs, and device drivers. ROM 1219 may be configured to provide computer instructions or data to processing circuitry 1201. For example, ROM 1219 may be configured to store invariant low-level system code or data for basic system functions such as basic input and output (I/O), startup, or reception of keystrokes from a keyboard that are stored in a non-volatile memory. Storage medium 1221 may be configured to include memory such as RAM, ROM, programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), magnetic disks, optical disks, floppy disks, hard disks, removable cartridges, or flash drives. In one example, storage medium 1221 may be configured to include operating system 1223, application program 1225 such as a web browser application, a widget or gadget engine or another application, and data file 1227. Storage medium 1221 may store, for use by UE 1200, any of a variety of various operating systems or combinations of operating systems.

[0162] Storage medium 1221 may be configured to include a number of physical drive units, such as redundant array of independent disks (RAID), floppy disk drive, flash memory, USB flash drive, external hard disk drive, thumb drive, pen drive, key drive, high-density digital versatile disc (HD-DVD) optical disc drive, internal hard disk drive, Blu-Ray optical disc drive, holographic digital data storage (HDDS) optical disc drive, external mini-dual in-line memory module (DIMM), synchronous dynamic random access memory (SDRAM), external micro-DIMM SDRAM, smartcard memory such as a subscriber identity module or a removable user identity (SIM/RUIM) module, other memory, or any combination thereof. Storage medium 1221 may allow UE 1200 to access computer-executable instructions, application programs or the like, stored on transitory or non-transitory memory media, to off-load data, or to upload data. An article of manufacture, such as one utilizing a communication system may be tangibly embodied in storage medium 1221, which may comprise a device readable medium.

[0163] In Figure 12, processing circuitry 1201 may be configured to communicate with network 1243b using communication subsystem 1231. Network 1243a and network 1243b may be the same network or networks or different network or networks. Communication subsystem 1231 may be configured to include one or more transceivers used to communicate with network 1243b. For example, communication subsystem 1231 may be configured to include one or more transceivers used to communicate with one or more remote transceivers of another device capable of wireless communication such as another WD, UE, or base station of a radio access network (RAN) according to one or more communication protocols, such as IEEE 802.QQ2, CDMA, WCDMA, GSM, LTE, UTRAN, WiMax, or the like. Each transceiver may

include transmitter 1233 and/or receiver 1235 to implement transmitter or receiver functionality, respectively, appropriate to the RAN links (e.g., frequency allocations and the like). Further, transmitter 1233 and receiver 1235 of each transceiver may share circuit components, software or firmware, or alternatively may be implemented separately.

[0164] In the illustrated embodiment, the communication functions of communication subsystem 1231 may include data communication, voice communication, multimedia communication, short-range communications such as Bluetooth, near-field communication, location-based communication such as the use of the global positioning system (GPS) to determine a location, another like communication function, or any combination thereof. For example, communication subsystem 1231 may include cellular communication, Wi-Fi communication, Bluetooth communication, and GPS communication. Network 1243b may encompass wired and/or wireless networks such as a local-area network (LAN), a wide-area network (WAN), a computer network, a wireless network, a telecommunications network, another like network or any combination thereof. For example, network 1243b may be a cellular network, a Wi-Fi network, and/or a near-field network. Power source 1213 may be configured to provide alternating current (AC) or direct current (DC) power to components of UE 1200.

[0165] The features, benefits and/or functions described herein may be implemented in one of the components of UE 1200 or partitioned across multiple components of UE 1200. Further, the features, benefits, and/or functions described herein may be implemented in any combination of hardware, software or firmware. In one example, communication subsystem 1231 may be configured to include any of the components described herein. Further, processing circuitry 1201 may be configured to communicate with any of such components over bus 1202. In another example, any of such components may be represented by program instructions stored in memory that when executed by processing circuitry 1201 perform the corresponding functions described herein. In another example, the functionality of any of such components may be partitioned between processing circuitry 1201 and communication subsystem 1231. In another example, the non-computationally intensive functions of any of such components may be implemented in software or firmware and the computationally intensive functions may be implemented in hardware.

[0166] Figure 13 is a schematic block diagram illustrating a virtualization environment 1300 in which functions implemented by some embodiments may be virtualized. In the present context, virtualizing means creating virtual versions of apparatuses or devices which may include virtualizing hardware platforms, storage devices and networking resources. As used herein, virtualization can be applied to a node (e.g., a virtualized base station or a virtualized radio access node) or to a device (e.g., a UE, a wireless device or any other type of communication device) or components thereof and relates to an implementation in which at least a portion of the functionality is implemented as one or more virtual components (e.g., via one or more applications, components, functions, virtual machines or containers executing on one or more physical processing nodes in one or more networks).

[0167] In some embodiments, some or all of the functions described herein may be implemented as virtual components executed by one or more virtual machines implemented in one or more virtual environments 1300 hosted by one or more of hardware nodes 1330. Further, in embodiments in which the virtual node is not a radio access node or does not require radio connectivity (e.g., a core network node), then the network node may be entirely virtualized.

[0168] The functions may be implemented by one or more applications 1320 (which may alternatively be called software instances, virtual appliances, network functions, virtual nodes, virtual network functions, etc.) operative to implement some of the features, functions, and/or benefits of some of the embodiments disclosed herein. Applications 1320 are run in virtualization environment 1300 which provides hardware 1330 comprising processing circuitry 1360 and memory 1390. Memory 1390 contains instructions 1395 executable by processing circuitry 1360 whereby application 1320 is operative to provide one or more of the features, benefits, and/or functions disclosed herein.

[0169] Virtualization environment 1300, comprises general-purpose or special-purpose network hardware devices 1330 comprising a set of one or more processors or processing circuitry 1360, which may be commercial off-the-shelf (COTS) processors, dedicated Application Specific Integrated Circuits (ASICs), or any other type of processing circuitry including digital or analog hardware components or special purpose processors. Each hardware device may comprise memory 1390-1 which may be non-persistent memory for temporarily storing instructions 1395 or software executed by processing circuitry 1360. Each hardware device may comprise one or more network interface controllers (NICs) 1370, also known as network interface cards, which include physical network interface 1380. Each hardware device may also include non-transitory, persistent, machine-readable storage media 1390-2 having stored therein software 1395 and/or instructions executable by processing circuitry 1360. Software 1395 may include any type of software including software for instantiating one or more virtualization layers 1350 (also referred to as hypervisors), software to execute virtual machines 1340 as well as software allowing it to execute functions, features and/or benefits described in relation with some embodiments described herein.

[0170] Virtual machines 1340, comprise virtual processing, virtual memory, virtual networking or interface and virtual storage, and may be run by a corresponding virtualization layer 1350 or hypervisor. Different embodiments of the instance of virtual appliance 1320 may be implemented on one or more of virtual machines 1340, and the implementations may be made in different ways.

[0171] During operation, processing circuitry 1360 executes software 1395 to instantiate the hypervisor or virtualization layer 1350, which may sometimes be referred to as a virtual machine monitor (VMM). Virtualization layer 1350 may present a virtual operating platform that appears like networking hardware to virtual machine 1340.

[0172] As shown in Figure 13, hardware 1330 may be a standalone network node with generic

or specific components. Hardware 1330 may comprise antenna 13225 and may implement some functions via virtualization. Alternatively, hardware 1330 may be part of a larger cluster of hardware (e.g. such as in a data center or customer premise equipment (CPE)) where many hardware nodes work together and are managed via management and orchestration (MANO) 13100, which, among others, oversees lifecycle management of applications 1320.

[0173] Virtualization of the hardware is in some contexts referred to as network function virtualization (NFV). NFV may be used to consolidate many network equipment types onto industry standard high volume server hardware, physical switches, and physical storage, which can be located in data centers, and customer premise equipment.

[0174] In the context of NFV, virtual machine 1340 may be a software implementation of a physical machine that runs programs as if they were executing on a physical, non-virtualized machine. Each of virtual machines 1340, and that part of hardware 1330 that executes that virtual machine, be it hardware dedicated to that virtual machine and/or hardware shared by that virtual machine with others of the virtual machines 1340, forms a separate virtual network elements (VNE).

[0175] Still in the context of NFV, Virtual Network Function (VNF) is responsible for handling specific network functions that run in one or more virtual machines 1340 on top of hardware networking infrastructure 1330 and corresponds to application 1320 in Figure 13.

[0176] In some embodiments, one or more radio units 13200 that each include one or more transmitters 13220 and one or more receivers 13210 may be coupled to one or more antennas 13225. Radio units 13200 may communicate directly with hardware nodes 1330 via one or more appropriate network interfaces and may be used in combination with the virtual components to provide a virtual node with radio capabilities, such as a radio access node or a base station.

[0177] In some embodiments, some signaling can be effected with the use of control system 13230 which may alternatively be used for communication between the hardware nodes 1330 and radio units 13200.

[0178] With reference to Figure 14, in accordance with an embodiment, a communication system includes telecommunication network 1410, such as a 3GPP-type cellular network, which comprises access network 1411, such as a radio access network, and core network 1414. Access network 1411 comprises a plurality of base stations 1412a, 1412b, 1412c, such as NBs, eNBs, gNBs or other types of wireless access points, each defining a corresponding coverage area 1413a, 1413b, 1413c. Each base station 1412a, 1412b, 1412c is connectable to core network 1414 over a wired or wireless connection 1415. A first UE 1491 located in coverage area 1413c is configured to wirelessly connect to, or be paged by, the corresponding base station 1412c. A second UE 1492 in coverage area 1413a is wirelessly connectable to the corresponding base station 1412a. While a plurality of UEs 1491, 1492 are illustrated in this example, the disclosed embodiments are equally applicable to a situation where a sole UE is in

the coverage area or where a sole UE is connecting to the corresponding base station 1412.

[0179] Telecommunication network 1410 is itself connected to host computer 1430, 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. Host computer 1430 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. Connections 1421 and 1422 between telecommunication network 1410 and host computer 1430 may extend directly from core network 1414 to host computer 1430 or may go via an optional intermediate network 1420. Intermediate network 1420 may be one of, or a combination of more than one of, a public, private or hosted network; intermediate network 1420, if any, may be a backbone network or the Internet; in particular, intermediate network 1420 may comprise two or more sub-networks (not shown).

[0180] The communication system of Figure 14 as a whole enables connectivity between the connected UEs 1491, 1492 and host computer 1430. The connectivity may be described as an over-the-top (OTT) connection 1450. Host computer 1430 and the connected UEs 1491, 1492 are configured to communicate data and/or signaling via OTT connection 1450, using access network 1411, core network 1414, any intermediate network 1420 and possible further infrastructure (not shown) as intermediaries. OTT connection 1450 may be transparent in the sense that the participating communication devices through which OTT connection 1450 passes are unaware of routing of uplink and downlink communications. For example, base station 1412 may not or need not be informed about the past routing of an incoming downlink communication with data originating from host computer 1430 to be forwarded (e.g., handed over) to a connected UE 1491. Similarly, base station 1412 need not be aware of the future routing of an outgoing uplink communication originating from the UE 1491 towards the host computer 1430.

[0181] Example implementations, in accordance with an embodiment, of the UE, base station and host computer discussed in the preceding paragraphs will now be described with reference to Figure 15. In communication system 1500, host computer 1510 comprises hardware 1515 including communication interface 1516 configured to set up and maintain a wired or wireless connection with an interface of a different communication device of communication system 1500. Host computer 1510 further comprises processing circuitry 1518, which may have storage and/or processing capabilities. In particular, processing circuitry 1518 may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. Host computer 1510 further comprises software 1511, which is stored in or accessible by host computer 1510 and executable by processing circuitry 1518. Software 1511 includes host application 1512. Host application 1512 may be operable to provide a service to a remote user, such as UE 1530 connecting via OTT connection 1550 terminating at UE 1530 and host computer 1510. In providing the service to the remote user, host application 1512 may provide user data which is transmitted using OTT connection 1550.

[0182] Communication system 1500 further includes base station 1520 provided in a telecommunication system and comprising hardware 1525 enabling it to communicate with host computer 1510 and with UE 1530. Hardware 1525 may include communication interface 1526 for setting up and maintaining a wired or wireless connection with an interface of a different communication device of communication system 1500, as well as radio interface 1527 for setting up and maintaining at least wireless connection 1570 with UE 1530 located in a coverage area (not shown in Figure 15) served by base station 1520. Communication interface 1526 may be configured to facilitate connection 1560 to host computer 1510. Connection 1560 may be direct or it may pass through a core network (not shown in Figure 15) of the telecommunication system and/or through one or more intermediate networks outside the telecommunication system. In the embodiment shown, hardware 1525 of base station 1520 further includes processing circuitry 1528, which may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. Base station 1520 further has software 1521 stored internally or accessible via an external connection.

[0183] Communication system 1500 further includes UE 1530 already referred to. Its hardware 1535 may include radio interface 1537 configured to set up and maintain wireless connection 1570 with a base station serving a coverage area in which UE 1530 is currently located. Hardware 1535 of UE 1530 further includes processing circuitry 1538, which may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. UE 1530 further comprises software 1531, which is stored in or accessible by UE 1530 and executable by processing circuitry 1538. Software 1531 includes client application 1532. Client application 1532 may be operable to provide a service to a human or non-human user via UE 1530, with the support of host computer 1510. In host computer 1510, an executing host application 1512 may communicate with the executing client application 1532 via OTT connection 1550 terminating at UE 1530 and host computer 1510. In providing the service to the user, client application 1532 may receive request data from host application 1512 and provide user data in response to the request data. OTT connection 1550 may transfer both the request data and the user data. Client application 1532 may interact with the user to generate the user data that it provides.

[0184] It is noted that host computer 1510, base station 1520 and UE 1530 illustrated in Figure 15 may be similar or identical to host computer 1430, one of base stations 1412a, 1412b, 1412c and one of UEs 1491, 1492 of Figure 14, respectively. This is to say, the inner workings of these entities may be as shown in Figure 15 and independently, the surrounding network topology may be that of Figure 14.

[0185] In Figure 15, OTT connection 1550 has been drawn abstractly to illustrate the communication between host computer 1510 and UE 1530 via base station 1520, 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 UE 1530 or from the service provider operating host computer 1510, or both. While OTT

connection 1550 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).

[0186] 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 OTT connection 1550 between host computer 1510 and UE 1530, in response to variations in the measurement results. The measurement procedure and/or the network functionality for reconfiguring OTT connection 1550 may be implemented in software 1511 and hardware 1515 of host computer 1510 or in software 1531 and hardware 1535 of UE 1530, or both. In embodiments, sensors (not shown) may be deployed in or in association with communication devices through which OTT connection 1550 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 1511, 1531 may compute or estimate the monitored quantities. The reconfiguring of OTT connection 1550 may include message format, retransmission settings, preferred routing etc.; the reconfiguring need not affect base station 1520, and it may be unknown or imperceptible to base station 1520. Such procedures and functionalities may be known and practiced in the art. In certain embodiments, measurements may involve proprietary UE signaling facilitating host computer 1510's measurements of throughput, propagation times, latency and the like. The measurements may be implemented in that software 1511 and 1531 causes messages to be transmitted, in particular empty or 'dummy' messages, using OTT connection 1550 while it monitors propagation times, errors etc.

[0187] The term unit may have conventional meaning in the field of electronics, electrical devices and/or electronic devices and may include, for example, electrical and/or electronic circuitry, devices, modules, processors, memories, logic solid state and/or discrete devices, computer programs or instructions for carrying out respective tasks, procedures, computations, outputs, and/or displaying functions, and so on, as such as those that are described herein.

[0188] Reference is now made to Figure 16, which is a block diagram illustrating operations of methods of operating a wireless communication device according to some embodiments herein. Such methods 1600 may include determining a timing advance (TA) offset for uplink/downlink switching (block 1601). Some embodiments provide that the TA offset is based on a time offset requirement for uplink/downlink switching in different configurations used in communication between the wireless communication device and a network node. Some embodiments provide that the wireless communication device includes a user equipment (UE). In some embodiments, the TA offset is predefined constant value for a particular frequency band and a particular frame structure and the particular frame structure includes one of a plurality of duplex modes.

[0189] In some embodiments, the TA offset is included in a TA command (TAC). In some embodiments, the TA offset value depends on the frequency band. Some embodiments

provide that the TA offset has a first TA offset value for a first frequency band that is below a frequency threshold for a time division duplex and a second TA offset value for a second frequency band that is equal to or above the frequency threshold.

[0190] Some embodiments provide that the first TA offset value is different than the second TA offset value. For example, some embodiments provide that the first TA offset value is greater than the second TA offset value. In some embodiments, the TA offset is 0 for non-time division duplex (non-TDD). In some embodiments, the frequency threshold is about 6GHz. In such embodiments, the first TA offset may be about 20μs, and the second TA offset may be about 10μs. Such values are non-limiting examples as the frequency threshold may be more or less than 6Ghz, the first TA offset may be more or less than 20μs, and the second TA offset may be more or less than 10μs.

[0191] Embodiments may include applying the determined TA offset in an uplink communication from the wireless communication device to the network node (block 1602). In some embodiments, applying the TA offset may include applying a timing advance corresponding to a propagation delay between the wireless communication device and the network node, in addition to the TA offset.

[0192] Some embodiments include receiving a message including the TA offset from the network node (block 1603). In such embodiments, applying the determined TA offset may include applying the received TA offset.

[0193] Some embodiments provide that the timing advance corresponding to the propagation delay is sent from the network node in a TA command in a RAR message. The TA offset may use two or three bits in the message according to some embodiments. In some embodiments, the TA offset is independent of NR-LTE co-existence.

[0194] Reference is now made to Figure 17, which is a block diagram illustrating operations of methods of operating a network node according to some embodiments herein. Such methods 1700 may include determining a timing advance (TA) offset for uplink/downlink switching (block 1701). Some embodiments provide that the TA offset is based on a time offset requirement for uplink/downlink switching in different configurations used in communication between the network node and a wireless communication device. In some embodiments, the TA offset has a first TA offset value for a first frequency band that is below a frequency threshold for a time division duplex and a second TA offset value for a second frequency band that is equal to or above the frequency threshold. Thus, some embodiments provide that the first TA offset value is different than the second TA offset value. Some embodiments provide that the first TA offset value is greater than the second TA offset value.

[0195] In some embodiments, the TA offset corresponds to an uplink communication from the wireless communication device to the network node.

[0196] Embodiments may include sending the determined TA offset to the wireless

communication device (block 1702). In some embodiments, the TA offset is sent in a random access response (RAR) message, while in other embodiments the TA offset is included in a TA command (TAC). Some embodiments provide that the TA offset takes two or three bits.

[0197] Operations according to some embodiments include sending a timing advance corresponding to a propagation delay between the wireless communication device and the network node to the wireless communication device, in a TA command in a RAR message (block 1703).

[0198] Some embodiments provide that the TA offset value depends on the frequency band. For example, according to some non-limiting embodiments, the frequency threshold may be about 6GHz, the first TA offset may be about 20μs, and the second TA offset may be about 10μs. In some embodiments, a non-time division duplex (non-TDD) may use a TA offset of 0.

[0199] In some embodiments, the TA offset is predefined constant value, for a particular frequency band and a particular frame structure. Examples of different frame structures may include different duplex modes. Some embodiments provide that the TA offset is independent of NR-LTE co-existence.

REFERENCES CITED IN THE DESCRIPTION

Cited references

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Patent documents cited in the description

- CN2017110528W [0001]
- US20150230268A [0004]

Patentkrav

1. Fremgangsmåde (1600), der udføres af en trådløs kommunikationsindretning (301), omfattende:

bestemmelse (1601) af en tidsfremryknings-, TA,-forskydning til uplink-downlink-skift, hvor TA-forskydningen er afhængig af en dupleksmodus af en celle, hvor der sker en uplink-transmission fra den trådløse kommunikationsindretning til en netværksknude, og et frekvensbånd af uplink-transmissionen (302), hvor TA-forskydningen har en første TA-forskydningsværdi for et første frekvensbånd, som er under en frekvenstærskel for en tidsdelt dupleks, og en anden TA-forskydningsværdi for et andet frekvensbånd, som er større end eller lig med frekvenstærsklen; og

anvendelse (1602) af den bestemte TA-forskydning i uplink-transmissionen.

2. Fremgangsmåde ifølge krav 1, hvor TA-forskydningen er afhængig af, om frekvensbåndet er et første frekvensbånd eller et andet frekvensbånd, og hvor det første frekvensbånd er et frekvensbånd over 6 GHz, og det andet frekvensbånd er et frekvensbånd under 6 GHz.

3. Fremgangsmåde ifølge krav 1, hvor den første TA-forskydningsværdi er større end den anden TA-forskydningsværdi.

4. Fremgangsmåde ifølge krav 1, hvor anvendelse af TA-forskydningen yderligere omfatter:

anvendelse af en tidsfremrykning svarende til en propageringsforsinkelse mellem den trådløse kommunikationsindretning og netværksknuden ud over TA-forskydningen,

hvor tidsfremrykningen, som svarer til propageringsforsinkelsen, sendes fra netværksknuden i en TA-kommando i en RAR-besked.

5. Fremgangsmåde ifølge et af de foregående krav, hvor TA-forskydningen er en foruddefineret konstant værdi for et særligt frekvensbånd og en særlig rammestruktur.

6. Fremgangsmåde ifølge et af de foregående krav, hvor TA-forskydningen er uafhængig af NR-LTE-koeksistens.

7. Fremgangsmåde (1700), der udføres af en netværksknude (302), omfattende:
bestemmelse (1701) af en tidsfremryknings-, TA,-forskydning til uplink-downlink-skift, hvor TA-forskydningen er afhængig af en dupleksmodus og et frekvensbånd anvendt til kommunikation mellem netværksknuden og en trådløs kommunikationsindretning (301), hvor TA-forskydningen har en første TA-forskydningsværdi for et første frekvensbånd, som er under en frekvenstærskel for en tidsdelt dupleks, og en anden TA-forskydningsværdi for et andet frekvensbånd, som er større end eller lig med frekvenstærsklen;
sending (1702) af den bestemte TA-forskydning til den trådløse kommunikationsindretning.

8. Fremgangsmåde ifølge krav 7, yderligere omfattende sending (1703) af en tidsfremrykning svarende til en propageringsforsinkelse mellem den trådløse kommunikationsindretning og netværksknuden til den trådløse kommunikationsindretning, i en TA-kommando i en RAR-besked.

9. Fremgangsmåde ifølge et af kravene 7-8, hvor den første TA-forskydningsværdi er større end den anden TA-forskydningsværdi.

10. Fremgangsmåde ifølge et af kravene 7-9, hvor TA-forskydningen er en foruddefineret konstant værdi for et særligt frekvensbånd og en særlig rammestruktur.

11. Fremgangsmåde ifølge et af kravene 7-10, hvor TA-forskydningen er uafhængig af NR-LTE- koeksistens.

12. Indretning (800), som er konfigureret til at fungere som en trådløs kommunikationsindretning, omfattende:
mindst en processor (801); og
et ikke-midlertidigt computerlæsbart medium (802), som er tilkoblet den mindst ene processor, hvor det ikke-midlertidige læsbare medium indeholder instruktioner, som kan eksekveres af den mindst ene processor, hvor den mindst ene processor er konfigureret til at udføre fremgangsmåden ifølge et af kravene 1 til 6.

13. Indretning (800), som er konfigureret til at fungere som en netværksknude, omfattende:
mindst en processor (801); og
et ikke-midlertidigt computerlæsbart medium (802), som er tilkoblet den mindst ene processor, hvor det ikke-midlertidige læsbare medium indeholder instruktioner, som kan eksekveres af den mindst ene processor, hvor den mindst ene processor er konfigureret til at udføre fremgangsmåden ifølge et af kravene 7 til 11.

DRAWINGS

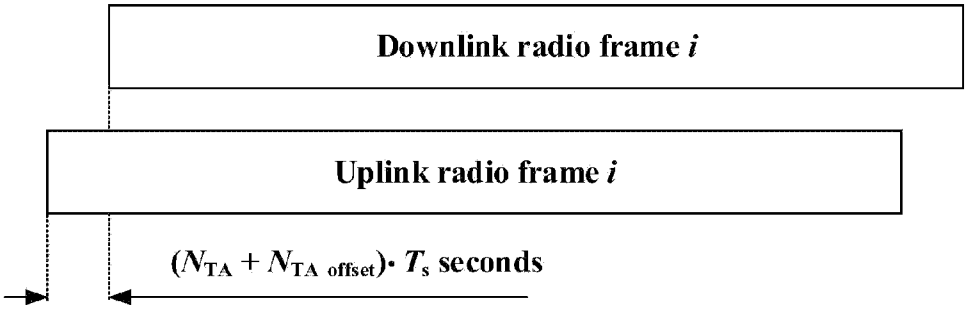


Figure 1

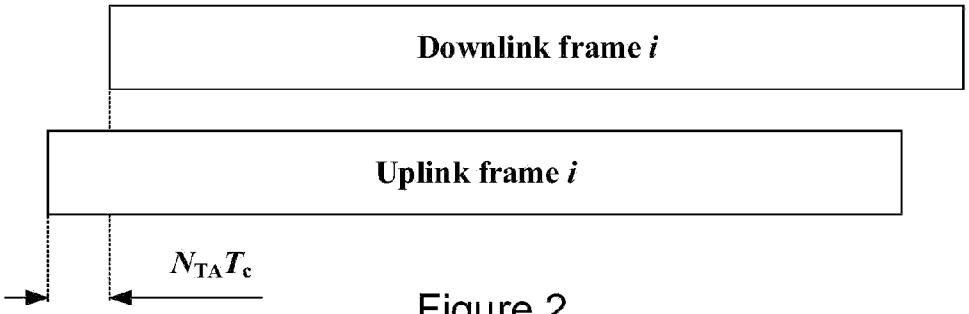


Figure 2

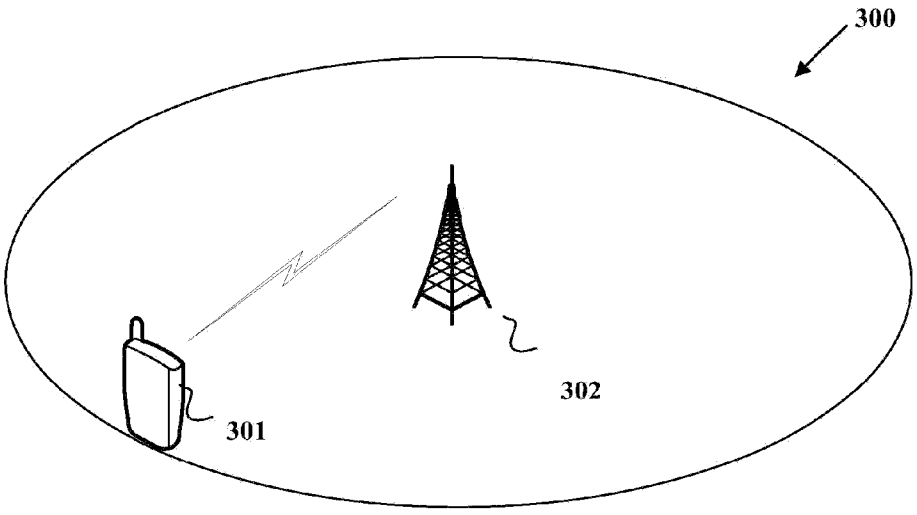


Figure 3

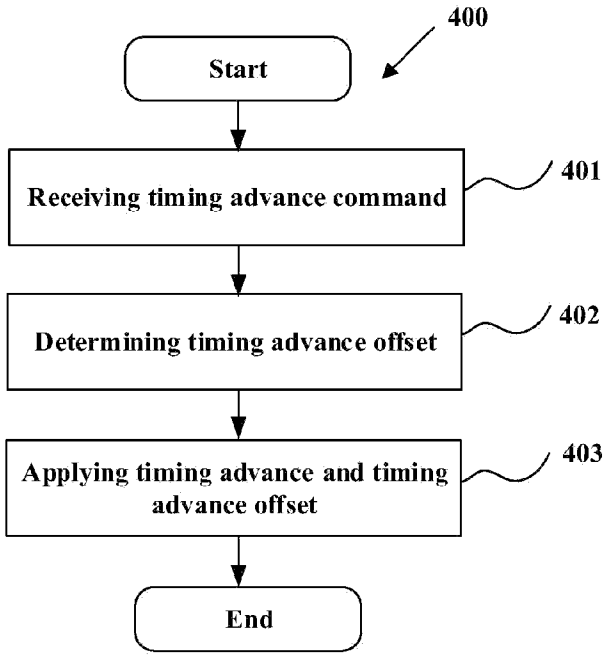


Figure 4

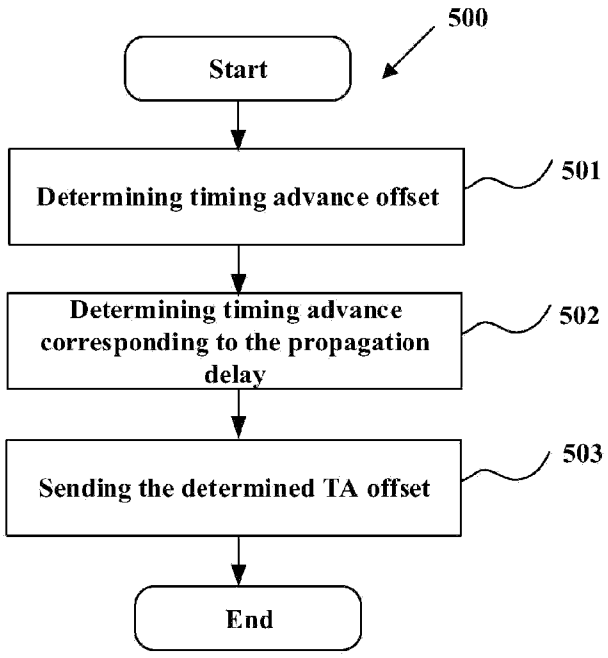


Figure 5

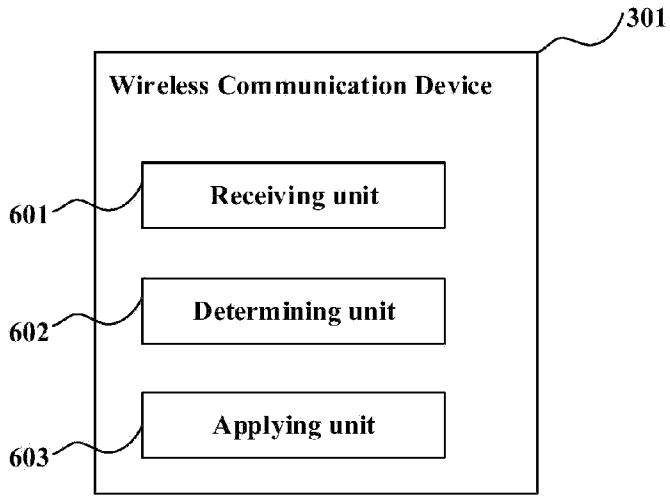


Figure 6

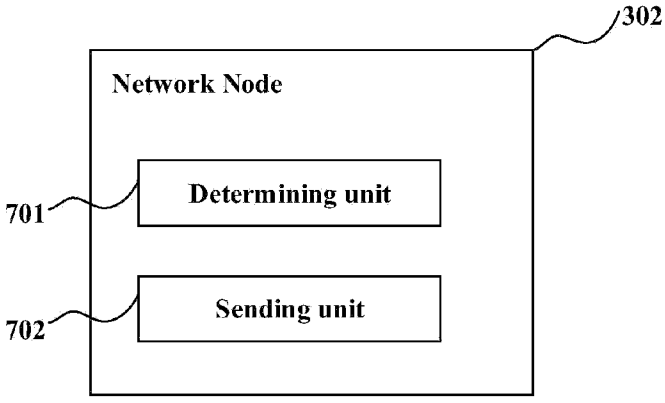


Figure 7

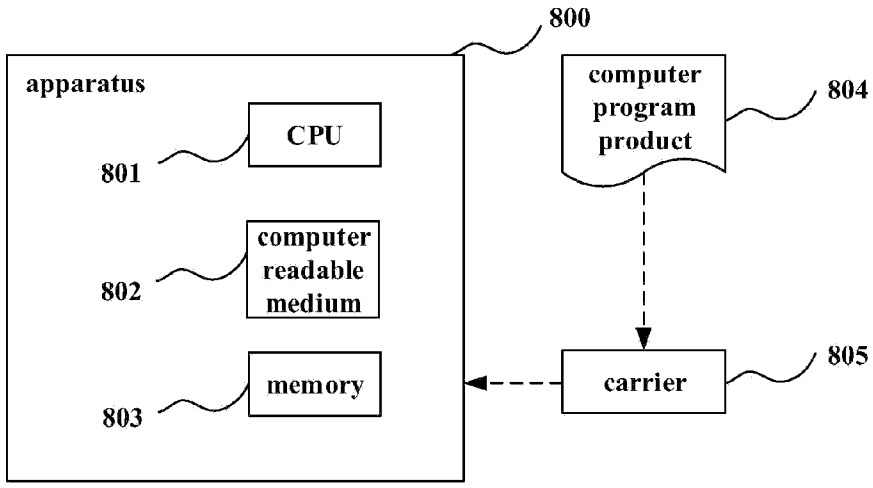

800
apparatus
CPU
801
computer readable medium
802
memory
803
computer program product
804
carrier
805

Figure 8

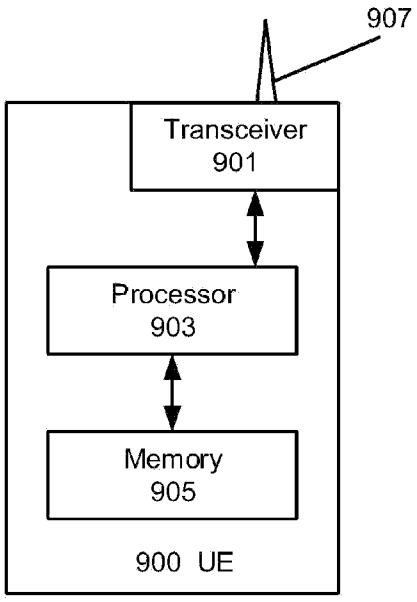


Figure 9

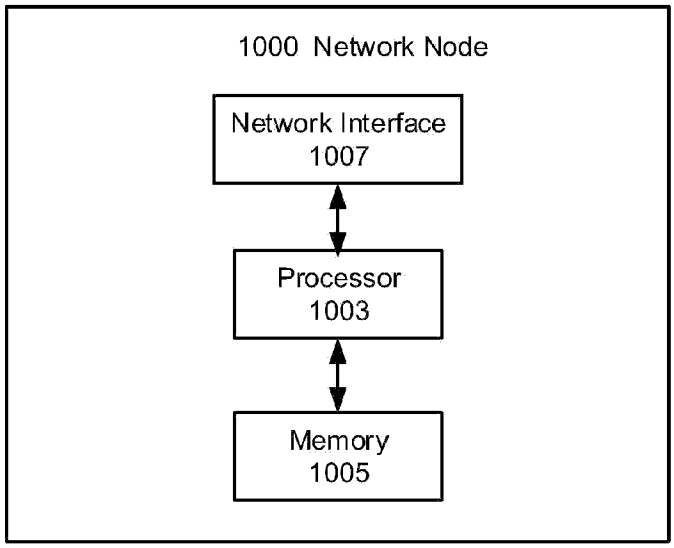


Figure 10

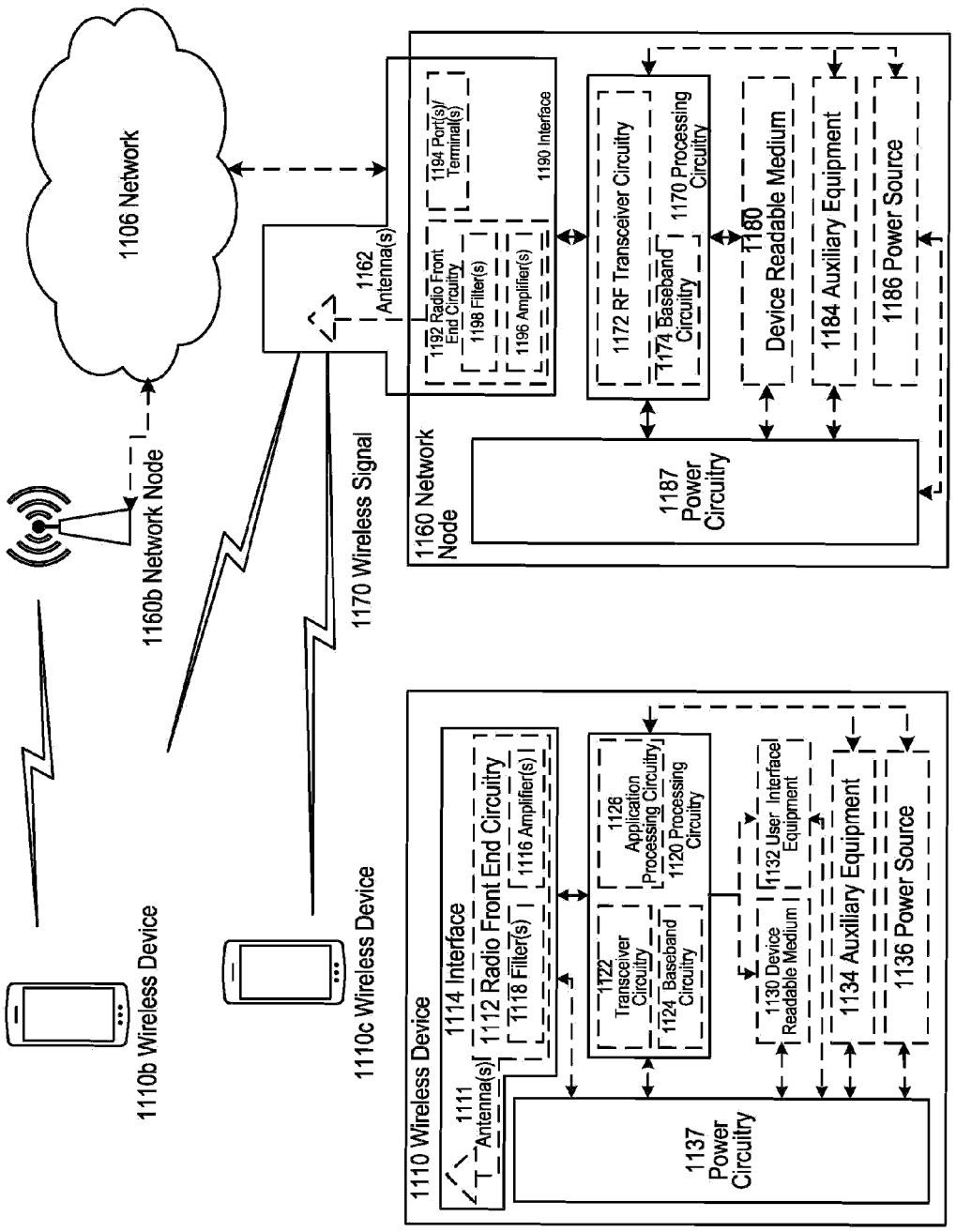

1106 Network
1160b Network Node
1110b Wireless Device
1110c Wireless Device
1170 Wireless Signal
1162 Antenna(s)
1160 Network Node
1192 Radio Front End Circuitry
1198 Filter(s)
1196 Amplifier(s)
1194 Port(s)/ Terminal(s)
1190 Interface
1172 RF Transceiver Circuitry
1174 Baseband Circuitry
1170 Processing Circuitry
1180 Device Readable Medium
1184 Auxiliary Equipment
1186 Power Source
1187 Power Circuitry
1110 Wireless Device
1111 Antenna(s)
1114 Interface
1112 Radio Front End Circuitry
1118 Filter(s)
1116 Amplifier(s)
1122 Transceiver Circuitry
1124 Baseband Circuitry
1126 Application Processing Circuitry
1120 Processing Circuitry
1130 Device Readable Medium
1132 User Interface Equipment
1134 Auxiliary Equipment
1136 Power Source
1137 Power Circuitry

Figure 11

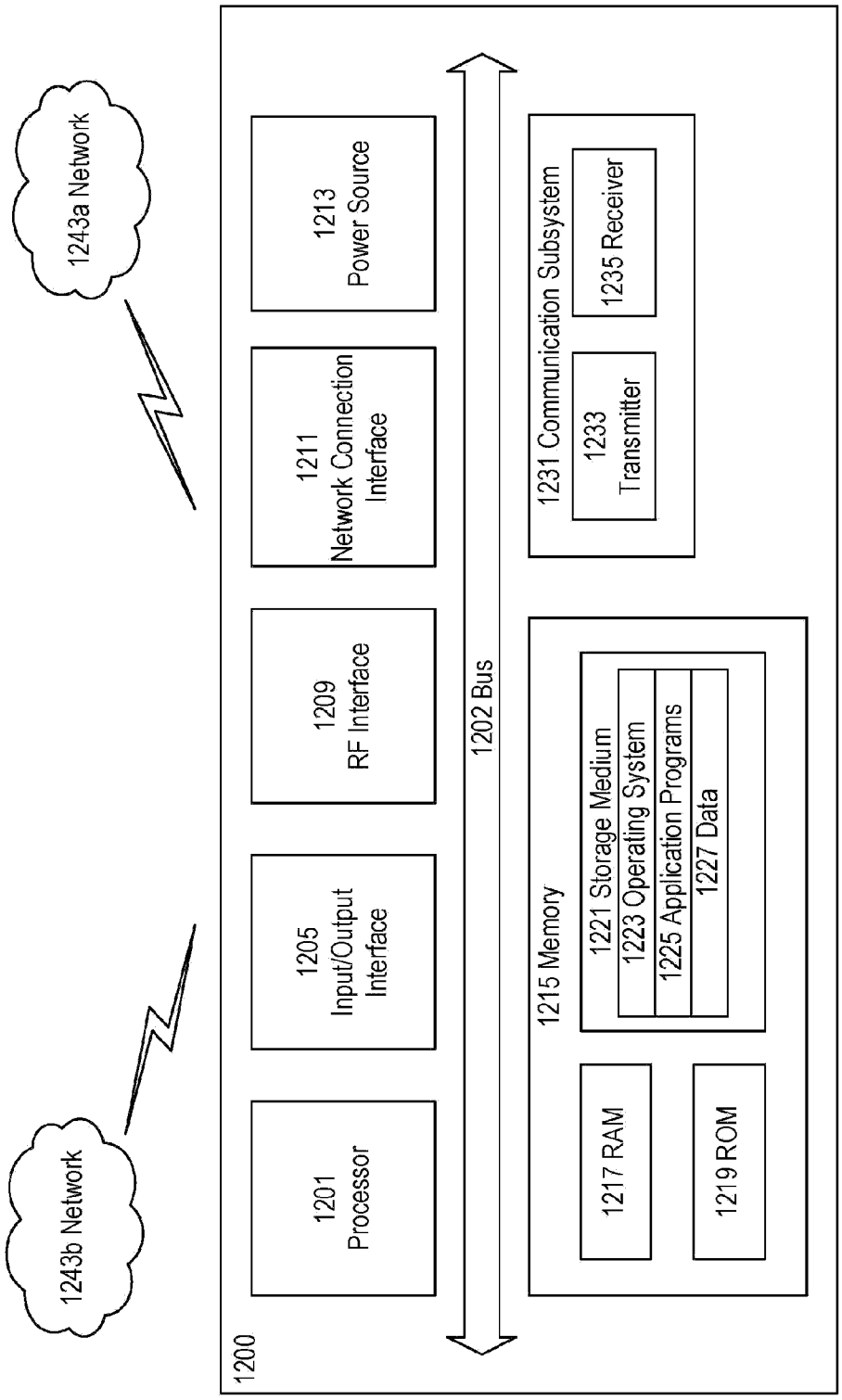

1243a Network
1243b Network
1200
1201 Processor
1205 Input/Output Interface
1209 RF Interface
1211 Network Connection Interface
1213 Power Source
1202 Bus
1215 Memory
1217 RAM
1219 ROM
1221 Storage Medium
1223 Operating System
1225 Application Programs
1227 Data
1231 Communication Subsystem
1233 Transmitter
1235 Receiver

Figure 12

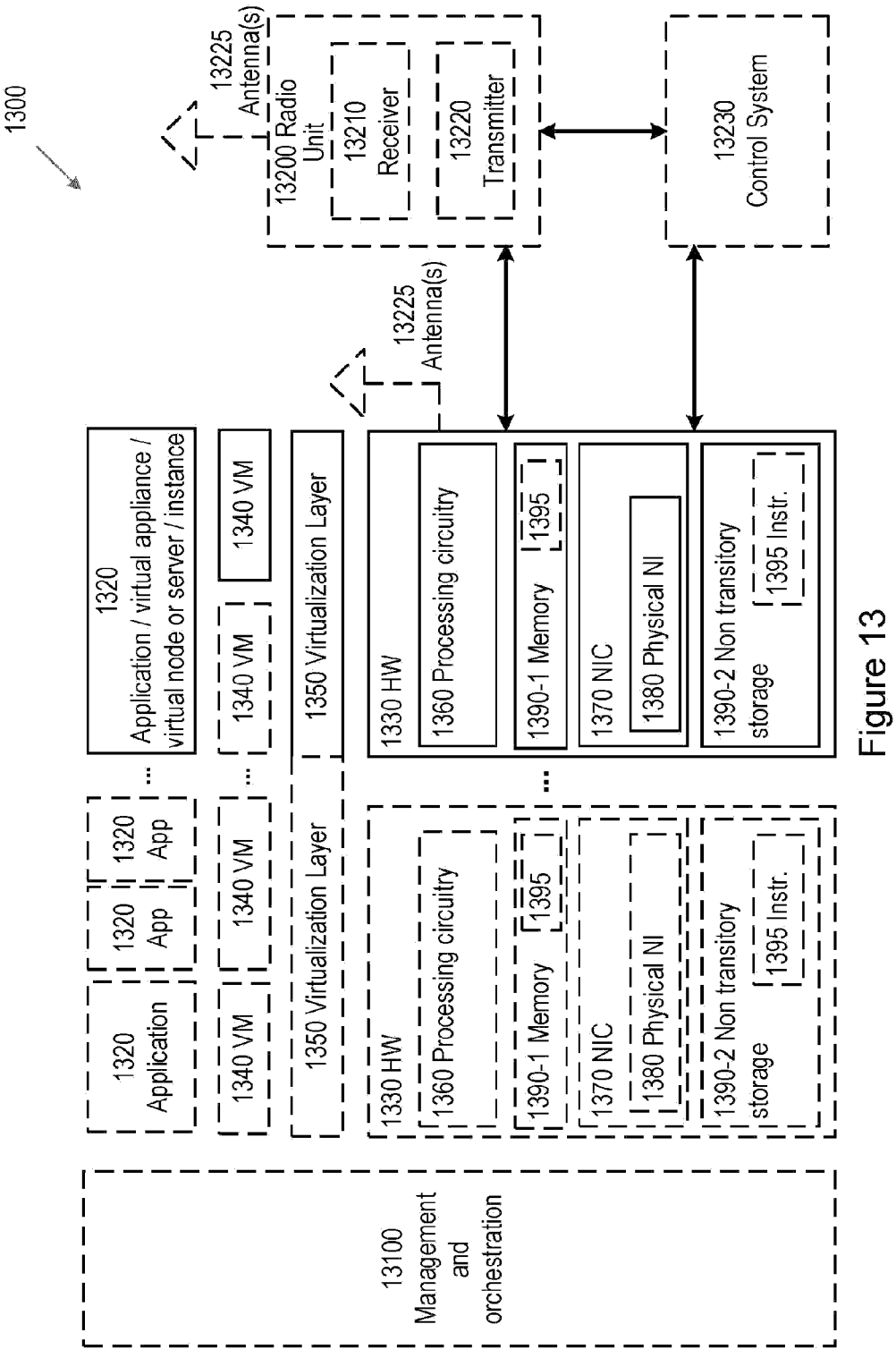

1300
13225 Antenna(s)
13200 Radio Unit
13210 Receiver
13220 Transmitter
13230 Control System
13225 Antenna(s)
1320 Application / virtual appliance / virtual node or server / instance
1340 VM
1350 Virtualization Layer
1330 HW
1360 Processing circuitry
1390-1 Memory
1395
1370 NIC
1380 Physical NI
1390-2 Non transitory storage
1395 Instr.
1320 Application
1320 App
13100 Management and orchestration

Figure 13

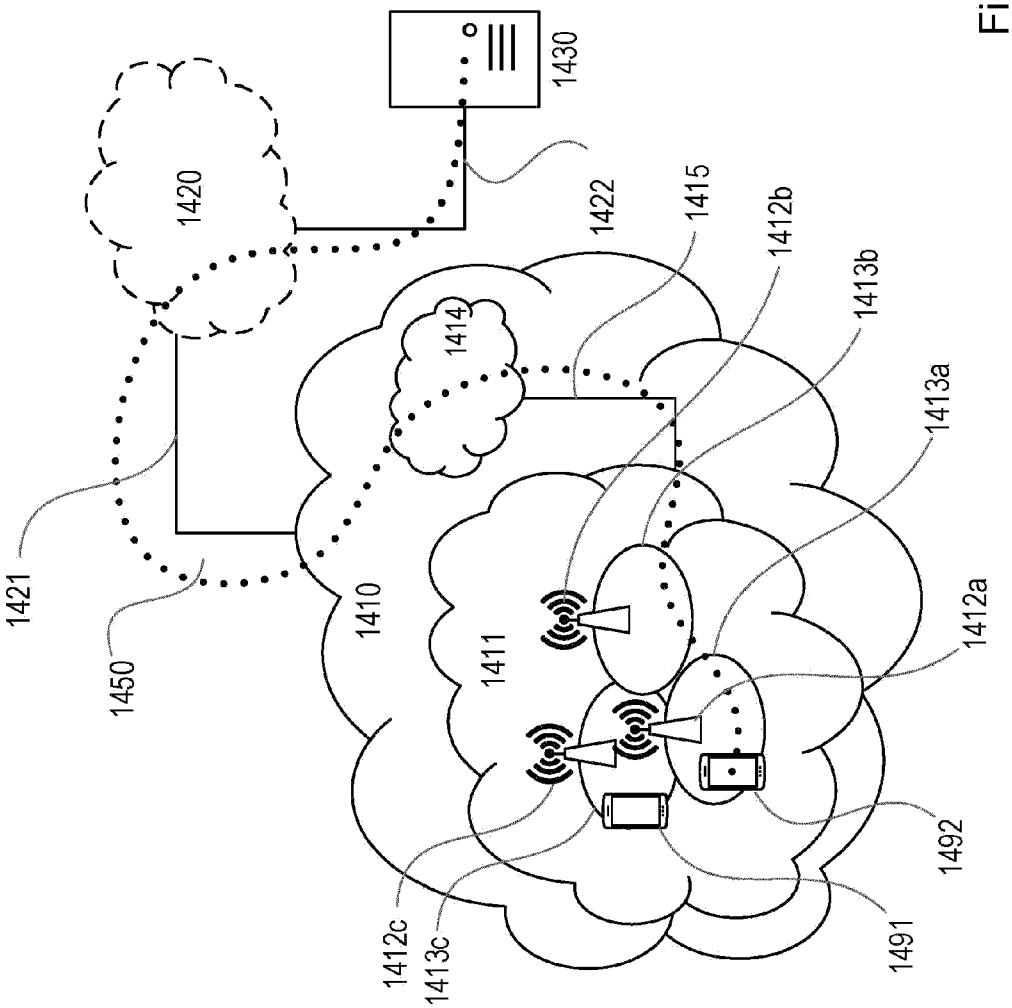

1430
1420
1422
1415
1412b
1413b
1414
1413a
1421
1410
1411
1412a
1450
1492
1412c
1413c
1491

Figure 14

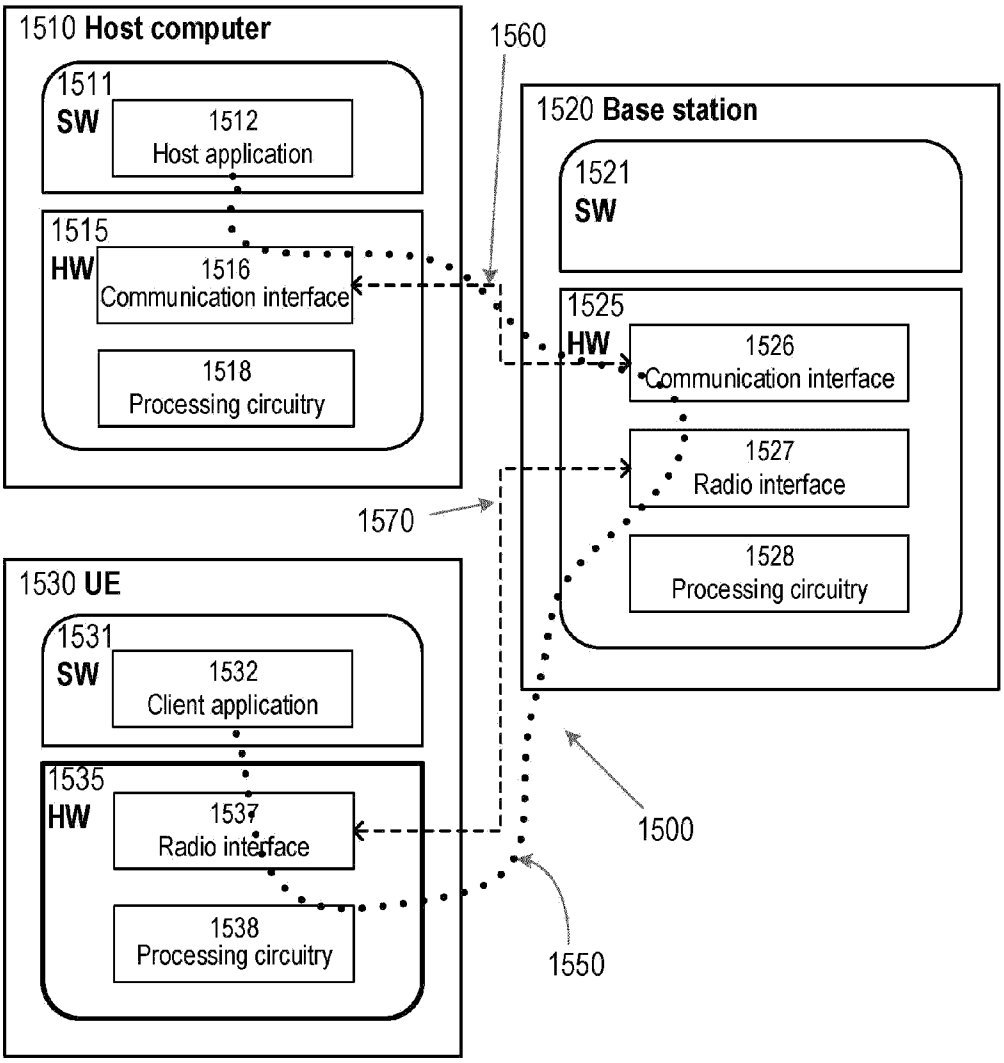

1510 Host computer
1511
SW
1512
Host application
1515
HW
1516
Communication interface
1518
Processing circuitry
1560
1520 Base station
1521
SW
1525
HW
1526
Communication interface
1527
Radio interface
1528
Processing circuitry
1570
1530 UE
1531
SW
1532
Client application
1535
HW
1537
Radio interface
1538
Processing circuitry
1500
1550

Figure 15

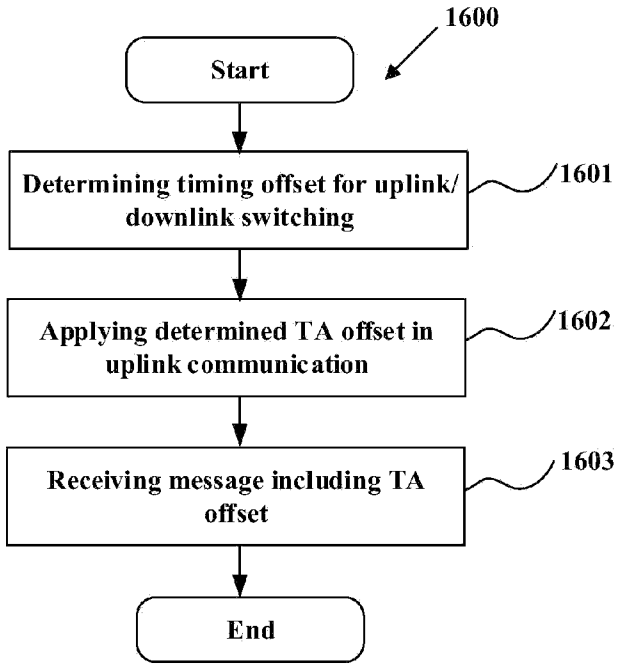

1600
Start
Determining timing offset for uplink/ downlink switching
1601
Applying determined TA offset in uplink communication
1602
Receiving message including TA offset
1603
End

Figure 16

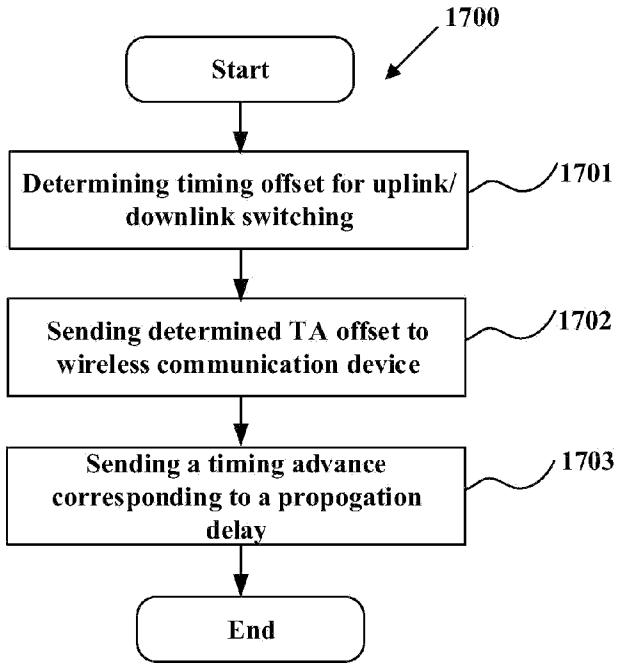

1700
Start
Determining timing offset for uplink/ downlink switching
1701
Sending determined TA offset to wireless communication device
1702
Sending a timing advance corresponding to a propogation delay
1703
End

Figure 17