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(54) Title: EFFICIENT TIME REFERENCE INFORMATION DELIVERY FOR MULTIPLE CLOCK DOMAINS

(57) Abstract: Systems, methods, apparatuses, and computer program products for efficient time reference information delivery for one or multiple clock domains are provided. In accordance with an example embodiment of the present invention, a method comprising: receiving, at a user equipment associated with a network, an indication of availability of clock information from the network; requesting information for at least one clock domain from the network; and receiving, from the network, the information for the at least one clock domain according to a determined periodicity.

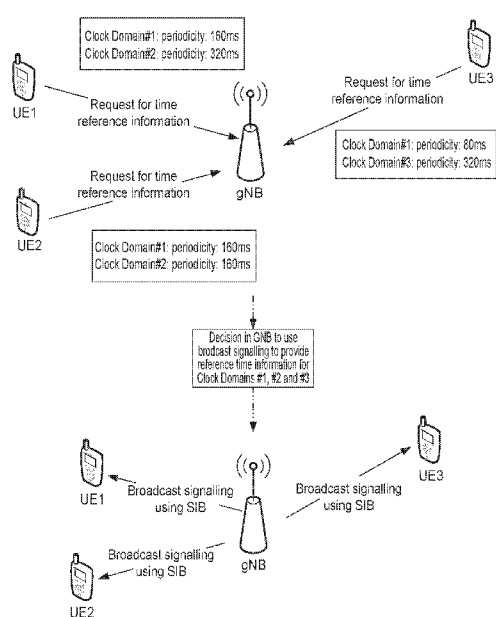


Fig. 3



EFFICIENT TIME REFERENCE INFORMATION DELIVERY FOR MULTIPLE CLOCK DOMAINS

FIELD:

5 [0001] Some example embodiments may generally relate to mobile or wireless telecommunication systems, such as Long Term Evolution (LTE) or fifth generation (5G) radio access technology or new radio (NR) access technology, or other communications systems. For example, certain embodiments may relate to systems and/or methods for time reference information delivery.

10 BACKGROUND:

[0002] Examples of mobile or wireless telecommunication systems may include the Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (UTRAN), Long Term Evolution (LTE) Evolved UTRAN (E-UTRAN), LTE-Advanced (LTE-A), MulteFire, LTE-A Pro, and/or fifth generation (5G) radio access technology or
15 new radio (NR) access technology. 5G wireless systems refer to the next generation (NG) of radio systems and network architecture. 5G is mostly built on a new radio (NR), but a 5G (or NG) network can also build on E-UTRA radio. It is estimated that NR provides bitrates on the order of 10-20 Gbit/s or higher, and can support at least enhanced mobile broadband (eMBB) and ultra-reliable low-latency-communication (URLLC) as well as
20 massive machine type communication (mMTC). NR is expected to deliver extreme broadband and ultra-robust, low latency connectivity and massive networking to support the Internet of Things (IoT). With IoT and machine-to-machine (M2M) communication becoming more widespread, there will be a growing need for networks that meet the needs of lower power, low data rate, and long battery life. It is noted that, in 5G, the nodes that
25 can provide radio access functionality to a user equipment (i.e., similar to Node B in UTRAN or eNB in LTE) may be named gNB when built on NR radio and may be named NG-eNB when built on E-UTRA radio.

SUMMARY:

30 [0003] Various aspects of examples of the invention are set out in the claims.

[0004] According to a first aspect of the present invention, a method comprising: transmitting, by a network, an indication of availability of clock information; receiving a request to provide information for at least one specific clock domain; and transmitting the information for the at least one specific clock domain according to a determined
35 periodicity of time reference information signaling for the at least one clock domain.

[0005] According to a second aspect of the present invention, an apparatus comprising: at least one processor; and at least one memory including computer program code, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to at least: transmit an indication of availability of
5 clock information; receive a request to provide information for at least one specific clock domain; and transmit the information for the at least one specific clock domain according to a determined periodicity of time reference information signaling for the at least one clock domain.

[0006] According to a third aspect of the present invention, A non-transitory computer
10 storage medium encoded with a computer program, the program comprising instructions that when executed by one or more computers cause the one or more computers to perform operations comprising: transmitting, by a network, an indication of availability of clock information; receiving a request to provide information for at least one specific clock domain; and transmitting the information for the at least one specific clock domain
15 according to a determined periodicity of time reference information signaling for the at least one clock domain.

[0007] According to a fourth aspect of the present invention, a method comprising: receiving, at a user equipment associated with a network, an indication of availability of clock information from the network; requesting information for at least one clock domain
20 from the network; and receiving, from the network, the information for the at least one clock domain according to a determined periodicity.

[0008] According to a fifth aspect of the present invention, an apparatus comprising: at least one processor; and at least one memory including computer program code, wherein the at least one memory and the computer program code are configured, with the at least
25 one processor, to cause the apparatus to at least: receive an indication of availability of clock information from a network; request information for at least one clock domain from the network; and receive, from the network, the information for the at least one clock domain according to a determined periodicity.

[0009] According to a sixth aspect of the present invention, A non-transitory computer
30 storage medium encoded with a computer program, the program comprising instructions that when executed by one or more computers cause the one or more computers to perform operations comprising: receiving, at a user equipment associated with a network, an indication of availability of clock information from the network; requesting information

for at least one clock domain from the network; and receiving, from the network, the information for the at least one clock domain according to a determined periodicity.

BRIEF DESCRIPTION OF THE DRAWINGS:

5 [00010] For proper understanding of example embodiments, reference should be made to the accompanying drawings, wherein:

[00011] Fig. 1 illustrates an example system diagram, according to an embodiment;

[00012] Fig. 2 illustrates an example system diagram, according to another
10 embodiment;

[00013] Fig. 3 illustrates a diagram of an example procedure for providing reference time to the UE(S), according to one embodiment;

[00014] Fig. 4 illustrates an example of populating SIB contents, according to an embodiment;

15 [00015] Fig. 5a illustrates an example flow diagram of a method, according to an embodiment;

[00016] Fig. 5b illustrates an example flow diagram of a method, according to an embodiment;

[0010] Fig. 6a illustrates an example block diagram of an apparatus, according to an
20 embodiment; and

[0011] Fig. 6b illustrates an example block diagram of an apparatus, according to another embodiment.

DETAILED DESCRIPTION:

25 [0012] It will be readily understood that the components of certain example embodiments, as generally described and illustrated in the figures herein, may be arranged and designed in a wide variety of different configurations. Thus, the following detailed description of some example embodiments of systems, methods, apparatuses, and computer program products for efficient time reference information delivery for multiple
30 clock domains, is not intended to limit the scope of certain embodiments but is representative of selected example embodiments.

[0013] The features, structures, or characteristics of example embodiments described throughout this specification may be combined in any suitable manner in one or more example embodiments. For example, the usage of the phrases “certain embodiments,”

“some embodiments,” or other similar language, throughout this specification refers to the fact that a particular feature, structure, or characteristic described in connection with an embodiment may be included in at least one embodiment. Thus, appearances of the phrases “in certain embodiments,” “in some embodiments,” “in other embodiments,” or other similar language, throughout this specification do not necessarily all refer to the same group of embodiments, and the described features, structures, or characteristics may be combined in any suitable manner in one or more example embodiments.

[0014] Additionally, if desired, the different functions or steps discussed below may be performed in a different order and/or concurrently with each other. Furthermore, if desired, one or more of the described functions or steps may be optional or may be combined. As such, the following description should be considered as merely illustrative of the principles and teachings of certain example embodiments, and not in limitation thereof.

[0015] Time Sensitive Communications (TSC) is a type of communications which supports applications requiring the involved end devices (e.g., UEs, IoT devices, etc.) to be strictly synchronised with each other, for example in the order of 10 μ s or 1 μ s. Some example use cases where TSC may be applicable include, but are not limited to, factory automation, robotic arm control, smart grid controls, etc. One of the standards to support TSC is called Time Sensitive Networking (TSN) and is specified in a set of standards by IEEE (e.g., IEEE 802.1Qv, 802.1AS). These standards are based on wired Ethernet as a transport layer; however due to ease of deployment, operation and potential cost reductions, there is a willingness from industries using those standards to move to wireless based technology. 5G is seen as a standard that can be fit to meet very stringent requirements in terms of both latency and reliability as well as highly precise synchronization accuracy of the applications running over TSN networks. As a result, the 3rd generation partnership project (3GPP) began work on enhancements for 5G/NR system to support TSN networks, and one of the requirements is to ensure precise clock synchronization can be provided to the TSN end devices operating in a 5G/NR system.

[0016] Clock synchronization requirements are captured in section 5.6 of 3GPP technical specification (TS) 22.104. Some of the clock synchronization requirements relate to support of multiple clock domains. For example, the 5G system shall support two types of synchronization clocks, the global time domain and the working clock domains. Additionally, the 5G system shall support networks with up to 32 working clock domains. The domain number (synchronization domain identifier) is defined with one octet in IEEE

802.1AS. This allows for 256 synchronization domains. The 5G system shall support at least two simultaneous working clock domains on a user equipment (UE).

[0017] 3GPP RAN working groups are studying synchronization accuracy achievable in NR system, as well as the ways to deliver accurate reference time information efficiently from a gNB to a UE as part of NR Industrial IoT (IIoT) Study Item (RP-182090). Time Sensitive Networking related enhancements include accurate reference timing: delivery & related process (e.g., SIB delivery or RRC delivery to UEs, Multiple Transmission points). With respect to this objective, it was captured in 3GPP technical report (TR) 38.825 that the LTE approach can be reused for time distribution by broadcast or unicast RRC signalling as a baseline and that a granularity of signaled time information should be no worse than 50ns, with the possibility of finer granularity than 50ns.

[0018] Broadcast radio resource control (RRC), i.e., System Information (SI), may be used for the delivery of accurate reference timing information to the UE(s). However, in case multiple clock domains are to be delivered to the UE(s), such information may be quite large resulting in high signalling overhead in the system and worse SI reception performance. In some cases, it might even exceed the maximum SI message size and not fit into a single SI message. Other issues to consider include that additional clock domains are usually useful for a subset of UEs in the cell only. Additionally, the required frequency of reference timing information for different clocks varies and may depend on the clocks' quality (e.g., clocks of higher quality / lower stratum level may need to be updated less often than clocks of lower quality / higher stratum level for the same requirement on synchronization accuracy) and/or an applications' requirement on synchronization accuracy (e.g., in case the clocks of the same quality / stratum level are used, then the clock of the application requiring higher synchronization precision (e.g., <1μs) needs to be updated with reference time information more often than the one linked to an application with less stringent synchronization accuracy requirement (e.g., <10μs)).

[0019] Certain embodiments provide a method of delivering reference timing information for multiple clock domains in an efficient way, while considering at least the factors mentioned above.

[0020] Delivering time reference information with system information block (SIB)/RRC signalling was specified in 3GPP Release-15 for LTE, but it allows for only a single clock domain to be provided. Section 6.11.1 of 3GPP TR 23.734 specifies support for multiple clock domains. One option is for multiple time domains to be merged into one domain using 5G clock.

[0021] Fig. 1 illustrates an example system diagram depicting the option in which the different time domains are merged into one time domain. In this option, a single clock domain is sufficient and a suitable one could be provided by the 5G system itself (in fact, it normally has to operate synchronous with an internationally recognized standard such as GPS). In the example of Fig. 1, the UE(s) 101 only receives 5G timing information through gNB 105, and acts as master clock to the TSN end stations 102. The TSN bridges 108 and end stations 110 at the right side of Fig. 1 also receive timing information from the 5G GM 120 via user plane function (UPF) 130 and underlying precision time protocol (PTP) compatible transport network 135. Therefore, all connected domains are locked to the 5GS clock (same universal time; all working clock domains synchronous to the universal time).

[0022] In this case, each interface of the 5G system is seen by the connected TSN networks and by the end stations 110, as separate GMs, each of them operating in independent generalized PTP (gPTP) domains, but providing the same time to all the connected networks. For example, the 5G clock at the transport function (TP) of the UPF is acting as TSN GM and provides GM reference to the TSN work domain 1 and work domain 2 on the right side of Fig. 1. The 5G clock at UEs 101 acts as TSN GM for the end stations 110 that belonging to TSN work domain 1 and 2, respectively.

[0023] Fig. 2 illustrates an example system diagram of an alternative option that can be an implementation with a 5G blackbox model. In such an implementation, the impact on the 5G system nodes will be small. As illustrated in the example of Fig. 2, the translator/adaptor function 160, located at the edge of 5G system, can take care of all 802.1AS related functions. For example, the (g)PTP support, time stamping, etc. can be all implemented in the translator. In some examples, the translator function 160 can be implemented either as part of UPF/UE, or as a stand-alone entity.

[0024] Therefore, one proposed solution may rely on TSN translators/adaptors to translate a single domain's clock (5G GM) into multiple clock domains used in different TSN networks. This has the advantage of not having to provide additional clock domains via RRC signalling from gNB to UE. On the other hand, such a solution may require additional functionality in the translator function (which is supposed to be specified by 3GPP), and the TSN clock information might be required anyway in the gNB for proper scheduling of TSN deterministic traffic while with that solution such timing information is not provided to the gNB.

[0025] As introduced above, example embodiments provide a process to support time delivery for multiple clock domains. In an embodiment, the time reference information for multiple clock domains may be provided to the gNB. For example, the time reference information may be provided, e.g., with a usage of Precision Time Protocol (PTP) or
5 generalized PTP (gPTP), global positioning system (GPS), or some other means. As referred to herein, the “reference information” may be a full timing information for a clock from multiple domains, and/or may be provided as a combination of full timing information for a single domain (called further Primary Domain Clock or PDC) and, for other clocks, a UE may be provided with time and/or frequency offset between the PDC
10 and the clocks of additional domains.

[0026] In certain embodiments, the network (e.g. a gNB) may signal the information about availability of the clock domains (e.g., clock ID, clock domain ID [0..255] etc.) for which the network has the available reference time information. As an example, the signaling may be done via broadcast (i.e., using System Information signalling) or unicast
15 RRC signaling. Part of the information may be carried out, for instance, via NAS signaling, such as mapping of gPTP clock domain identifiers to clock identifiers used, for example, in RRC. According to one example, for each of the clocks, the network (e.g., gNB) may also indicate whether a certain clock domain is currently signaled via SIB and with which periodicity.

20 [0027] In some embodiments, based on the network configuration and current knowledge of the necessity to provide a certain clock domain, the network (e.g., gNB) may decide whether to provide it in at least one of the following ways: with a periodic broadcast signalling, with a unicast signalling to specific UEs, and/or not provide a time reference for a certain clock domain at all but still signal its availability in the gNB.

25 [0028] In case the time reference information for a clock domain in which the UE is interested in is not currently provided, but its availability in the gNB is indicated by the gNB, the UE may request the gNB to provide the time reference information for a specific clock. For example, the UE may send the request using a unicast RRC message (e.g., UEAssistanceInformation or another existing or new RRC message) indicating the clock
30 domain(s) of interest, which are not yet provided. Additionally, in an embodiment, the UE may provide an assistance information about the preferred periodicity of time reference information signalling for each of the requested clock domains (e.g., depending on the clocks’ quality and/or service’s synchronization accuracy requirement). Alternatively, in

an embodiment, the UE may provide the synchronization accuracy requirement for a specific clock so that required periodicity can be determined by the gNB.

[0029] According to certain embodiments, based on the requests from the UEs in the cell, the gNB can make a decision whether to provide the time reference information to the
5 UE via unicast or broadcast RRC signalling. In case broadcast signalling is used, the gNB may further populate the contents of the System Information Block (SIB) providing the time reference information considering the clock domains and their respective periodicities as requested by the UEs. The periodicity of SIB signalling may be determined based on the shortest of the periodicities requested by the UE for any of the requested clock
10 domains. According to an embodiment, in each SIB instance signalling, the gNB may just include time reference for the clock domains in such a way that the minimum periodicity as requested by at least one of the UEs is met (or according to the periodicity as determined by the gNB based on the known clock quality and service synchronization requirement as communicated by the UE).

15 [0030] Over time, there may be new requests arriving at the gNB to add new clock domains signalling or some UEs may also move away from the cell's coverage. Based on that, in some embodiments, the gNB may decide to change the SIB periodicity and/or contents with respect to contained clock domains.

[0031] Figs. 3 and 4 depict an example of a proposed procedure for clock domains
20 requested with various periodicity by the UEs. More specifically, Fig. 3 illustrates a diagram of an example procedure for providing reference time to the UEs, according to one embodiment. As illustrated in the example of Fig. 3, UE1 may request Clock Domain #1 with 160 ms periodicity and Clock Domain #2 with 320 ms periodicity, UE2 may request Clock Domain #1 with 160 ms periodicity and Clock Domain #2 with 160 ms
25 periodicity, and UE3 may request Clock Domain #1 with 80 ms periodicity and Clock Domain #3 with 320ms periodicity. Based on these requests, the gNB may decide to use broadcast signalling to provide time reference for Clock Domains #1, #2 and #3. The gNB may also populate the relevant SIB in at least the following way: SIB contains time reference information for all three Clock Domains every 320 ms, SIB contains time
30 reference information for Clock Domain #1 every 80 ms, and/or SIB contains time reference information for Clock Domain #1 and #2 every 160 ms. Fig. 4 illustrates an example of how the gNB may efficiently populate SIB contents based on requests from the UEs, according to certain embodiments.

[0032] Therefore, example embodiments allow delivery of one or more clock domains in an efficient way, such as only in case a certain clock is required for at least some UEs in the cell and/or with a periodicity that is required for a given service with a given clock quality. This way, each clock may be provided in the SIB in a manner allowing for use of
5 the physical resources in the cell efficiently and at the same time meet the synchronization accuracy requirements of the applications served by the UEs.

[0033] Certain embodiments may also be implemented by taking advantage of on-demand system information request and delivery. In this case, for example, the different clock domain(s) may be provided via different SIBs mapped to different SI messages
10 (potentially having different periodicities). According to an embodiment, the gNB may signal the mapping between clock domain(s), SIBs and SIs providing them. The UE, using other SI request procedure with either MSG1 or MSG3 (depending on network configuration and as currently specified), may request the gNB to provide SI messages containing SIBs containing the clock domain(s) of interest. Then, the gNB may either start
15 broadcasting the requested SI messages or provide them to the UE via unicast signalling, for example. According to an embodiment, in case the periodicity of signalling of time reference information of a particular clock domain does not meet the requirement from the UE, the UE may inform the gNB about that using dedicated RRC signalling. Based on that information, the gNB may adapt periodicity of certain SI messages or remap
20 corresponding SIBs to SI messages with sufficient periodicity.

[0034] Alternatively, in one embodiment, all the clock domain(s) can be provided by a single SIB mapped to a single SI message. In that case, in addition to indicating the SI message of interest, an additional information may be sent by the UE to indicate which clock domain(s) it is interested in. For example, such indication may be realized via
25 additional physical random access channel (PRACH) preambles being associated to certain clock domain(s) (for msg1 based on demand SI delivery mechanism), via an additional indication in RRCSystemInfoRequest message (for msg3 based on demand SI delivery mechanism), or via for example UEAssistanceInformation for UEs in RRC Connected mode.

30 [0035] Fig. 5a illustrates an example flow diagram of a method for providing or delivering reference timing information for one or multiple clock domain(s), according to one example embodiment. In certain example embodiments, the flow diagram of Fig. 5a may be performed by a network entity or network node in a 3GPP system, such as LTE or

5G NR. For instance, in some example embodiments, the method of Fig. 5a may be performed by an access point, base station, eNB, gNB, or the like.

[0036] In one embodiment, the method may include, at 500, receiving time reference information for multiple clock domains. For example, the receiving 500 may include
5 receiving the time reference information using PTP or gPTP, GPS, or another means. According to an embodiment, the time reference information may include a full timing information for a clock from multiple domains, and/or may include a combination of full timing information for a single domain and frequency offset between the PDC and the clocks of additional domains.

10 [0037] In certain embodiments, the method may include, at 510, transmitting, to one or more UE(s), an indication of the availability of the information about the clock domains (e.g., clock ID, clock domain ID [0..255] etc.) for which the network has the available time reference information. In some example embodiments, the time reference information for the clock domains may include one or more of an identifier, a class, an epoch, a timescale,
15 a precision, a stability, a periodicity for transmission and/or a radio resource for the clock information.

[0038] According to some embodiments, the transmitting 510 may include transmitting the information to the UE(s) via broadcast (e.g., SI signalling) or transmitting the information using unicast RRC signaling. In some examples, part of the information may
20 be carried out, for instance, via NAS signaling, such as mapping of gPTP clock domain identifiers to clock identifiers used, for example, in RRC. According to one example, for each of the clocks, the transmitting 510 may include indicating whether a certain clock domain is currently signaled via SIB and with which periodicity.

[0039] In some embodiments, based on the network configuration and current
25 knowledge of the necessity to provide a certain clock domain, the method may include, at 520, deciding how to provide the information about the clock domains. For example, in certain embodiments, the deciding 520 may include deciding whether to provide the information about the clock domains with a periodic broadcast signalling, with a unicast signalling to specific UE(s), and/or not provide a time reference for a certain clock domain
30 at all but still signal its availability in the network node.

[0040] In case the time reference information for a clock domain in which the UE is interested in is not currently provided, but its availability in the network node is indicated, the method may optionally include, at 530, receiving from a UE a request to provide the time reference information for a specific clock. For example, the receiving 530 may

include receiving the request from the UE via a unicast RRC message (e.g., UEAssistanceInformation or another existing or new RRC message) indicating the clock domain(s) of interest, which are not yet provided. Additionally, in an embodiment, the receiving 530 may include receiving, from the UE, assistance information about the preferred periodicity of time reference information signalling for each of the requested clock domains (e.g., depending on the clocks' quality and/or service's synchronization accuracy requirement). For example, the assistance information may include an explicit indication of the preferred periodicity of the time reference information signaling for one or more of the requested clock domains. Alternatively, in an embodiment, the receiving 530 may include receiving, from the UE, the synchronization accuracy requirement for a specific clock or application so that required periodicity can be determined by the network node.

[0041] According to certain embodiments, based on the requests received from the UE(s) in the cell, the method may optionally include, at 540, deciding how to provide the time reference information to the UE(s), for example, via unicast or broadcast RRC signalling. For instance, the deciding 540 may include deciding, based on the network configuration and current knowledge of the necessity to provide a certain clock domain, how to provide the information about the clock domain(s). In certain embodiments, the deciding 540 may include deciding whether to provide the information about the clock domains with a periodic broadcast signalling, with a unicast signalling to specific UE(s), and/or not provide a time reference for a certain clock domain at all but still signal its availability in the network node.

[0042] In case broadcast signalling is used, the method may further include populating the contents of the SIB providing the time reference information considering the clock domains and their respective periodicities as requested by the UE(s). The periodicity of SIB signalling may be determined based on the shortest of the periodicities requested by the UE for any of the requested clock domains. According to an embodiment, in each SIB instance signalling, time reference for the clock domains may be included in such a way that the minimum periodicity as requested by at least one of the UE(s) is met or according to the periodicity as determined by the network node based on the known clock quality and service synchronization requirement as communicated by the UE(s).

[0043] In some embodiments, if there are new requests arriving at the network node to add new clock domains signalling and/or some UE(s) move away from the cell's coverage,

the network node may decide to change the SIB periodicity and/or contents with respect to contained clock domains.

[0044] Fig. 5b illustrates an example flow diagram of a method for providing or receiving reference timing information for multiple clock domains, according to one
5 example embodiment, according to one embodiment. In certain embodiments, the method of Fig. 5b may be performed by a mobile station, mobile device, UE, IoT device, terminal, or the like, for instance.

[0045] According to an embodiment, the method of Fig. 5b may include, at 550, receiving, from the network, an indication of the availability of information about one or
10 more clock domain(s) (e.g., clock ID, clock domain ID [0..255] etc.) for which the network has the available time reference information. In some example embodiments, the time reference information for the clock domains may include one or more of an identifier, a class, an epoch, a timescale, a precision, a stability, a periodicity for transmission and/or a radio resource for the clock information.

15 [0046] According to some embodiments, the receiving 550 may include receiving the information, from the network, via broadcast (e.g., SI signalling) or receiving the information using unicast RRC signaling. In some examples, part of the information may be received, for instance, via NAS signaling, such as mapping of gPTP clock domain identifiers to clock identifiers used, for example, in RRC. According to one example, for
20 each of the clocks, the receiving 550 may include receiving an indication of whether a certain clock domain is currently signaled via SIB and with which periodicity.

[0047] In some embodiments, the method may optionally include, at 560, determining the existence of needed information. For example, the determining 560 may include determining that the time reference information for a clock domain in which the UE is
25 interested in is not currently provided, but its availability in the network node is indicated. In an embodiment, the method may include, at 570, requesting from the network to provide the needed information for the clock domain, for example by requesting missing clock information such as the time reference information for a specific clock. For example, the requesting 570 may include transmitting the request via a unicast RRC message (e.g.,
30 UEAssistanceInformation or another existing or new RRC message) indicating the clock domain(s) of interest, which are not yet provided. Additionally, in an embodiment, the requesting 570 may further include transmitting, to the network, assistance information about the preferred periodicity of time reference information signalling for each of the requested clock domains (e.g., depending on the clocks' quality and/or service's

synchronization accuracy requirement). Alternatively, in an embodiment, the requesting 570 may include transmitting, to the network, the synchronization accuracy requirement for a specific clock so that required periodicity can be determined by the network. In an embodiment, the method may then include, at 580, receiving, from the network, the
5 information for the requested clock domain of interest according to the preferred or required periodicity.

[0048] According to another embodiment, the receiving 550 may include receiving the information that different clock domains are available via different SIBs mapped to different SI messages possibly having different periodicities. In an embodiment, the
10 receiving 550 may include receiving, from the network, the mapping between clock domain(s), SIBs and SIs providing them. In one embodiment, the requesting 570 may include requesting, e.g., using SI request procedure with either MSG1 or MSG3, the network to provide SI messages containing SIBs containing the clock domain(s) of interest. Then, the method may include receiving the requested SI messages from the
15 network via broadcast or via unicast signalling, for example. According to an embodiment, in case the periodicity of signalling of time reference information of a particular clock domain does not meet the requirement from the UE, the method may include informing the network about that using dedicated RRC signalling. Based on that information, the network may adapt the periodicity of certain SI messages or remap corresponding SIBs to
20 SI messages with sufficient periodicity.

[0049] Alternatively, in another embodiment, the receiving 550 may include receiving the clock domain(s) by a single SIB mapped to a single SI message. In that case, in addition to indicating the SI message of interest, the method may include sending an additional information to indicate which clock domain(s) the UE is interested in. For
25 example, such indication may be realized via additional physical random access channel (PRACH) preambles being associated to certain clock domain(s), via an additional indication in RRC System Information Request message, or via for example UE Assistance Information for UEs in RRC Connected mode.

[0050] Fig. 6a illustrates an example of an apparatus 10 according to an embodiment.
30 In an embodiment, apparatus 10 may be a node, host, or server in a communications network or serving such a network. For example, apparatus 10 may be a satellite, base station, a Node B, an evolved Node B (eNB), 5G Node B or access point, next generation Node B (NG-NB or gNB), and/or WLAN access point, associated with a radio access

network, such as a LTE network, 5G or NR. In example embodiments, apparatus 10 may be an eNB in LTE or gNB in 5G.

[0051] It should be understood that, in some example embodiments, apparatus 10 may be comprised of an edge cloud server as a distributed computing system where the server and the radio node may be stand-alone apparatuses communicating with each other via a radio path or via a wired connection, or they may be located in a same entity communicating via a wired connection. For instance, in certain example embodiments where apparatus 10 represents a gNB, it may be configured in a central unit (CU) and distributed unit (DU) architecture that divides the gNB functionality. In such an architecture, the CU may be a logical node that includes gNB functions such as transfer of user data, mobility control, radio access network sharing, positioning, and/or session management, etc. The CU may control the operation of DU(s) over a front-haul interface. The DU may be a logical node that includes a subset of the gNB functions, depending on the functional split option. It should be noted that one of ordinary skill in the art would understand that apparatus 10 may include components or features not shown in Fig. 6a.

[0052] As illustrated in the example of Fig. 6a, apparatus 10 may include a processor 12 for processing information and executing instructions or operations. Processor 12 may be any type of general or specific purpose processor. In fact, processor 12 may include one or more of general-purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), and processors based on a multi-core processor architecture, as examples. While a single processor 12 is shown in Fig. 6a, multiple processors may be utilized according to other embodiments. For example, it should be understood that, in certain embodiments, apparatus 10 may include two or more processors that may form a multiprocessor system (e.g., in this case processor 12 may represent a multiprocessor) that may support multiprocessing. In certain embodiments, the multiprocessor system may be tightly coupled or loosely coupled (e.g., to form a computer cluster).

[0053] Processor 12 may perform functions associated with the operation of apparatus 10, which may include, for example, precoding of antenna gain/phase parameters, encoding and decoding of individual bits forming a communication message, formatting of information, and overall control of the apparatus 10, including processes related to management of communication resources.

[0054] Apparatus 10 may further include or be coupled to a memory 14 (internal or external), which may be coupled to processor 12, for storing information and instructions that may be executed by processor 12. Memory 14 may be one or more memories and of any type suitable to the local application environment, and may be implemented using any
5 suitable volatile or nonvolatile data storage technology such as a semiconductor-based memory device, a magnetic memory device and system, an optical memory device and system, fixed memory, and/or removable memory. For example, memory 14 can be comprised of any combination of random access memory (RAM), read only memory (ROM), static storage such as a magnetic or optical disk, hard disk drive (HDD), or any
10 other type of non-transitory machine or computer readable media. The instructions stored in memory 14 may include program instructions or computer program code that, when executed by processor 12, enable the apparatus 10 to perform tasks as described herein.

[0055] In an embodiment, apparatus 10 may further include or be coupled to (internal or external) a drive or port that is configured to accept and read an external computer
15 readable storage medium, such as an optical disc, USB drive, flash drive, or any other storage medium. For example, the external computer readable storage medium may store a computer program or software for execution by processor 12 and/or apparatus 10.

[0056] In some embodiments, apparatus 10 may also include or be coupled to one or more antennas 15 for transmitting and receiving signals and/or data to and from apparatus
20 10. Apparatus 10 may further include or be coupled to a transceiver 18 configured to transmit and receive information. The transceiver 18 may include, for example, a plurality of radio interfaces that may be coupled to the antenna(s) 15. The radio interfaces may correspond to a plurality of radio access technologies including one or more of GSM, NB-IoT, LTE, 5G, WLAN, Bluetooth, BT-LE, NFC, radio frequency identifier (RFID),
25 ultrawideband (UWB), MulteFire, and the like. The radio interface may include components, such as filters, converters (for example, digital-to-analog converters and the like), mappers, a Fast Fourier Transform (FFT) module, and the like, to generate symbols for a transmission via one or more downlinks and to receive symbols (for example, via an uplink).

30 [0057] As such, transceiver 18 may be configured to modulate information on to a carrier waveform for transmission by the antenna(s) 15 and demodulate information received via the antenna(s) 15 for further processing by other elements of apparatus 10. In other embodiments, transceiver 18 may be capable of transmitting and receiving signals or

data directly. Additionally or alternatively, in some embodiments, apparatus 10 may include an input and/or output device (I/O device).

[0058] In an embodiment, memory 14 may store software modules that provide functionality when executed by processor 12. The modules may include, for example, an operating system that provides operating system functionality for apparatus 10. The memory may also store one or more functional modules, such as an application or program, to provide additional functionality for apparatus 10. The components of apparatus 10 may be implemented in hardware, or as any suitable combination of hardware and software.

10 [0059] According to some embodiments, processor 12 and memory 14 may be included in or may form a part of processing circuitry or control circuitry. In addition, in some embodiments, transceiver 18 may be included in or may form a part of transceiving circuitry.

[0060] As used herein, the term “circuitry” may refer to hardware-only circuitry implementations (e.g., analog and/or digital circuitry), combinations of hardware circuits and software, combinations of analog and/or digital hardware circuits with software/firmware, any portions of hardware processor(s) with software (including digital signal processors) that work together to case an apparatus (e.g., apparatus 10) to perform various functions, and/or hardware circuit(s) and/or processor(s), or portions thereof, that use software for operation but where the software may not be present when it is not needed for operation. As a further example, as used herein, the term “circuitry” may also cover an implementation of merely a hardware circuit or processor (or multiple processors), or portion of a hardware circuit or processor, and its accompanying software and/or firmware. The term circuitry may also cover, for example, a baseband integrated circuit in a server, cellular network node or device, or other computing or network device.

[0061] As introduced above, in certain embodiments, apparatus 10 may be a network node or RAN node, such as a base station, access point, Node B, eNB, gNB, WLAN access point, or the like. According to certain embodiments, apparatus 10 may be controlled by memory 14 and processor 12 to perform the functions associated with any of the embodiments described herein, such as the flow or signaling diagrams illustrated in Figs. 3, 4, 5a or 5b. In some embodiments, apparatus 10 may be configured to perform a procedure for delivering time reference information for multiple clock domains, for example.

[0062] For instance, in one embodiment, apparatus 10 may be controlled by memory 14 and processor 12 to receive time reference information for multiple clock domains. For example, apparatus 10 may be controlled by memory 14 and processor 12 to receive the time reference information using PTP or gPTP, GPS, or another means. According to an embodiment, the time reference information may include a full timing information for a clock from multiple domains, and/or may include a combination of full timing information for a single domain and frequency offset between the PDC and the clocks of additional domains.

[0063] In certain embodiments, apparatus 10 may be controlled by memory 14 and processor 12 to transmit, to one or more UE(s), an indication of the availability of the information about the clock domains (e.g., clock ID, clock domain ID [0.255] etc.) for which the apparatus 10 has the available time reference information. In some example embodiments, the time reference information for the clock domains may include one or more of an identifier, a class, an epoch, a timescale, a precision, a stability, a periodicity for transmission and/or a radio resource for the clock information.

[0064] According to some embodiments, apparatus 10 may be controlled by memory 14 and processor 12 to transmit the information to the UE(s) via broadcast (e.g., SI signalling) or to transmit the information using unicast RRC signaling. In some examples, part of the information may be carried out, for instance, via NAS signaling, such as mapping of gPTP clock domain identifiers to clock identifiers used, for example, in RRC. According to one example, for each of the clocks, apparatus 10 may be controlled by memory 14 and processor 12 to indicate whether a certain clock domain is currently signaled via SIB and with which periodicity.

[0065] In some embodiments, based on the network configuration and current knowledge of the necessity to provide a certain clock domain, apparatus 10 may be controlled by memory 14 and processor 12 to decide whether to provide the information about the clock domains with a periodic broadcast signalling, with a unicast signalling to specific UE(s), and/or to not provide a time reference for a certain clock domain at all but still signal its availability in the network node.

[0066] In case the time reference information for a clock domain in which the UE is interested in is not currently provided, but its availability in the apparatus 10 is indicated, apparatus 10 may be controlled by memory 14 and processor 12 to receive from the UE(s) a request to provide the time reference information for a specific clock. For example, apparatus 10 may be controlled by memory 14 and processor 12 to receive the request

from the UE(s) via a unicast RRC message (e.g., UEAssistanceInformation or another existing or new RRC message) indicating the clock domain(s) of interest, which are not yet provided. Additionally, in an embodiment, apparatus 10 may be controlled by memory 14 and processor 12 to receive, from the UE(s), assistance information about the preferred
5 periodicity of time reference information signalling for each of the requested clock domains (e.g., depending on the clocks' quality and/or service's synchronization accuracy requirement). Alternatively, in an embodiment, apparatus 10 may be controlled by memory 14 and processor 12 to receive, from the UE(s), the synchronization accuracy requirement for a specific clock so that required periodicity can be determined by the
10 apparatus 10.

[0067] According to certain embodiments, based on the requests received from the UE(s) in the cell, apparatus 10 may be controlled by memory 14 and processor 12 to decide whether to provide the time reference information to the UE(s) via unicast or broadcast RRC signalling. In case broadcast signalling is used, apparatus 10 may be
15 controlled by memory 14 and processor 12 to populate the contents of the SIB providing the time reference information considering the clock domains and their respective periodicities as requested by the UE(s). The periodicity of SIB signalling may be determined based on the shortest of the periodicities requested by the UE for any of the requested clock domains. According to an embodiment, in each SIB instance signalling,
20 apparatus 10 may be controlled by memory 14 and processor 12 to include time reference for the clock domains in such a way that the minimum periodicity as requested by at least one of the UE(s) is met or according to the periodicity as determined by the apparatus 10 based on the known clock quality and service synchronization requirement as communicated by the UE(s).

25 [0068] In some embodiments, if there are new requests arriving at the apparatus 10 to add new clock domains signalling and/or some UE(s) move away from the cell's coverage, apparatus 10 may be controlled by memory 14 and processor 12 to decide to change the SIB periodicity and/or contents with respect to contained clock domains.

[0069] Fig. 6b illustrates an example of an apparatus 20 according to another
30 embodiment. In an embodiment, apparatus 20 may be a node or element in a communications network or associated with such a network, such as a UE, mobile equipment (ME), mobile station, mobile device, stationary device, IoT device, or other device. As described herein, UE may alternatively be referred to as, for example, a mobile station, mobile equipment, mobile unit, mobile device, user device, subscriber station,

wireless terminal, tablet, smart phone, IoT device, sensor or NB-IoT device, or the like. As one example, apparatus 20 may be implemented in, for instance, a wireless handheld device, a wireless plug-in accessory, or the like.

[0070] In some example embodiments, apparatus 20 may include one or more
5 processors, one or more computer-readable storage medium (for example, memory, storage, or the like), one or more radio access components (for example, a modem, a transceiver, or the like), and/or a user interface. In some embodiments, apparatus 20 may be configured to operate using one or more radio access technologies, such as GSM, LTE, LTE-A, NR, 5G, WLAN, WiFi, NB-IoT, Bluetooth, NFC, MulteFire, and/or any other
10 radio access technologies. It should be noted that one of ordinary skill in the art would understand that apparatus 20 may include components or features not shown in Fig. 6b.

[0071] As illustrated in the example of Fig. 6b, apparatus 20 may include or be coupled to a processor 22 for processing information and executing instructions or operations. Processor 22 may be any type of general or specific purpose processor. In fact, processor
15 22 may include one or more of general-purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), and processors based on a multi-core processor architecture, as examples. While a single processor 22 is shown in Fig. 6b, multiple processors may be utilized according to other embodiments. For
20 example, it should be understood that, in certain embodiments, apparatus 20 may include two or more processors that may form a multiprocessor system (e.g., in this case processor 22 may represent a multiprocessor) that may support multiprocessing. In certain embodiments, the multiprocessor system may be tightly coupled or loosely coupled (e.g., to form a computer cluster).

25 [0072] Processor 22 may perform functions associated with the operation of apparatus 20 including, as some examples, precoding of antenna gain/phase parameters, encoding and decoding of individual bits forming a communication message, formatting of information, and overall control of the apparatus 20, including processes related to management of communication resources.

30 [0073] Apparatus 20 may further include or be coupled to a memory 24 (internal or external), which may be coupled to processor 22, for storing information and instructions that may be executed by processor 22. Memory 24 may be one or more memories and of any type suitable to the local application environment, and may be implemented using any suitable volatile or nonvolatile data storage technology such as a semiconductor-based

memory device, a magnetic memory device and system, an optical memory device and system, fixed memory, and/or removable memory. For example, memory 24 can be comprised of any combination of random access memory (RAM), read only memory (ROM), static storage such as a magnetic or optical disk, hard disk drive (HDD), or any
5 other type of non-transitory machine or computer readable media. The instructions stored in memory 24 may include program instructions or computer program code that, when executed by processor 22, enable the apparatus 20 to perform tasks as described herein.

[0074] In an embodiment, apparatus 20 may further include or be coupled to (internal or external) a drive or port that is configured to accept and read an external computer
10 readable storage medium, such as an optical disc, USB drive, flash drive, or any other storage medium. For example, the external computer readable storage medium may store a computer program or software for execution by processor 22 and/or apparatus 20.

[0075] In some embodiments, apparatus 20 may also include or be coupled to one or more antennas 25 for receiving a downlink signal and for transmitting via an uplink from
15 apparatus 20. Apparatus 20 may further include a transceiver 28 configured to transmit and receive information. The transceiver 28 may also include a radio interface (e.g., a modem) coupled to the antenna 25. The radio interface may correspond to a plurality of radio access technologies including one or more of GSM, LTE, LTE-A, 5G, NR, WLAN, NB-IoT, Bluetooth, BT-LE, NFC, RFID, UWB, and the like. The radio interface may
20 include other components, such as filters, converters (for example, digital-to-analog converters and the like), symbol demappers, signal shaping components, an Inverse Fast Fourier Transform (IFFT) module, and the like, to process symbols, such as OFDMA symbols, carried by a downlink or an uplink.

[0076] For instance, transceiver 28 may be configured to modulate information on to a
25 carrier waveform for transmission by the antenna(s) 25 and demodulate information received via the antenna(s) 25 for further processing by other elements of apparatus 20. In other embodiments, transceiver 28 may be capable of transmitting and receiving signals or data directly. Additionally or alternatively, in some embodiments, apparatus 10 may include an input and/or output device (I/O device). In certain embodiments, apparatus 20
30 may further include a user interface, such as a graphical user interface or touchscreen.

[0077] In an embodiment, memory 24 stores software modules that provide functionality when executed by processor 22. The modules may include, for example, an operating system that provides operating system functionality for apparatus 20. The memory may also store one or more functional modules, such as an application or

program, to provide additional functionality for apparatus 20. The components of apparatus 20 may be implemented in hardware, or as any suitable combination of hardware and software. According to an example embodiment, apparatus 20 may optionally be configured to communicate with apparatus 10 via a wireless or wired
5 communications link 70 according to any radio access technology, such as NR.

[0078] According to some embodiments, processor 22 and memory 24 may be included in or may form a part of processing circuitry or control circuitry. In addition, in some embodiments, transceiver 28 may be included in or may form a part of transceiving circuitry.

10 **[0079]** As discussed above, according to some embodiments, apparatus 20 may be a UE, mobile device, mobile station, ME, IoT device and/or NB-IoT device, for example. According to certain embodiments, apparatus 20 may be controlled by memory 24 and processor 22 to perform the functions associated with example embodiments described herein. For example, in some embodiments, apparatus 20 may be configured to perform
15 one or more of the processes depicted in any of the flow charts or signaling diagrams described herein, such as the flow diagrams illustrated in Figs. 5a or 5b. For example, in certain embodiments, apparatus 20 may be configured to perform a procedure for receiving time reference information for multiple clock domains, for instance.

[0080] According to some embodiments, apparatus 20 may be controlled by memory 24
20 and processor 22 to receive, from a network, an indication of the availability of information about multiple clock domains (e.g., clock ID, clock domain ID [0..255] etc.) for which the network has the available time reference information. In some example embodiments, the time reference information for the clock domains may include one or more of an identifier, a class, an epoch, a timescale, a precision, a stability, a periodicity
25 for transmission and/or a radio resource for the clock information.

[0081] According to some embodiments, apparatus 20 may be controlled by memory 24 and processor 22 to receive the information, from the network, via broadcast (e.g., SI signalling) or receiving the information using unicast RRC signaling. In some examples, part of the information may be received, for instance, via NAS signaling, such as mapping
30 of gPTP clock domain identifiers to clock identifiers used, for example, in RRC. According to one example, for each of the clocks, apparatus 20 may be controlled by memory 24 and processor 22 to receive an indication of whether a certain clock domain is currently signaled via SIB and with which periodicity.

[0082] In some embodiments, apparatus 20 may be controlled by memory 24 and processor 22 to determine the existence of needed information. For example, apparatus 20 may be controlled by memory 24 and processor 22 to determine that the time reference information for a clock domain in which the apparatus 20 is interested in is not currently
5 provided, but its availability at the network is indicated. In this case, in an embodiment, apparatus 20 may be controlled by memory 24 and processor 22 to request from the network to provide missing clock information, such as the time reference information for a specific clock. For example, apparatus 20 may be controlled by memory 24 and processor 22 to transmit the request via a unicast RRC message (e.g., UEAssistanceInformation or
10 another existing or new RRC message) indicating the clock domain(s) of interest, which are not yet provided. Additionally, in an embodiment, apparatus 20 may be controlled by memory 24 and processor 22 to transmit, to the network, assistance information about the preferred periodicity of time reference information signalling for each of the requested clock domains (e.g., depending on the clocks' quality and/or service's synchronization
15 accuracy requirement). Alternatively, in an embodiment, apparatus 20 may be controlled by memory 24 and processor 22 to transmit, to the network, the synchronization accuracy requirement for a specific clock so that required periodicity can be determined by the network.

[0083] Therefore, certain example embodiments provide several technical
20 improvements, enhancements, and/or advantages. For example, certain embodiments support the delivery of multiple clock domains in an efficient manner. For instance, in one embodiment, information on the multiple clock domains may be provided in the case a certain clock is required for at least some of the UE(s) in a cell. Also, in an embodiment, the information on the multiple clock domains can be provided with a periodicity that is
25 required for a given service with a given clock quality. As a result, in certain embodiments, each clock can be provided in the SIB in a way allowing for use of the physical resources in the cell efficiently and, at the same time, meet the synchronization accuracy requirements of the applications served by the UE(s). Accordingly, the use of certain example embodiments results in improved functioning of communications
30 networks and their nodes.

[0084] In some example embodiments, the functionality of any of the methods, processes, signaling diagrams, algorithms or flow charts described herein may be implemented by software and/or computer program code or portions of code stored in memory or other computer readable or tangible media, and executed by a processor.

[0085] In some example embodiments, an apparatus may be included or be associated with at least one software application, module, unit or entity configured as arithmetic operation(s), or as a program or portions of it (including an added or updated software routine), executed by at least one operation processor. Programs, also called program
5 products or computer programs, including software routines, applets and macros, may be stored in any apparatus-readable data storage medium and include program instructions to perform particular tasks.

[0086] A computer program product may comprise one or more computer-executable components which, when the program is run, are configured to carry out some example
10 embodiments. The one or more computer-executable components may be at least one software code or portions of it. Modifications and configurations required for implementing functionality of an example embodiment may be performed as routine(s), which may be implemented as added or updated software routine(s). Software routine(s) may be downloaded into the apparatus.

15 [0087] As an example, software or a computer program code or portions of it may be in a source code form, object code form, or in some intermediate form, and it may be stored in some sort of carrier, distribution medium, or computer readable medium, which may be any entity or device capable of carrying the program. Such carriers may include a record medium, computer memory, read-only memory, photoelectrical and/or electrical carrier
20 signal, telecommunications signal, and software distribution package, for example. Depending on the processing power needed, the computer program may be executed in a single electronic digital computer or it may be distributed amongst a number of computers. The computer readable medium or computer readable storage medium may be a non-transitory medium.

25 [0088] In other example embodiments, the functionality may be performed by hardware or circuitry included in an apparatus (e.g., apparatus 10 or apparatus 20), for example through the use of an application specific integrated circuit (ASIC), a programmable gate array (PGA), a field programmable gate array (FPGA), or any other combination of hardware and software. In yet another example embodiment, the functionality may be
30 implemented as a signal, a non-tangible means that can be carried by an electromagnetic signal downloaded from the Internet or other network.

[0089] According to an example embodiment, an apparatus, such as a node, device, or a corresponding component, may be configured as circuitry, a computer or a microprocessor, such as single-chip computer element, or as a chipset, including at least a

memory for providing storage capacity used for arithmetic operation and an operation processor for executing the arithmetic operation.

[0090] One having ordinary skill in the art will readily understand that the example embodiments as discussed above may be practiced with steps in a different order, and/or
5 with hardware elements in configurations which are different than those which are disclosed. Therefore, although some embodiments have been described based upon these example preferred embodiments, it would be apparent to those of skill in the art that certain modifications, variations, and alternative constructions would be apparent, while remaining within the spirit and scope of example embodiments.

We Claim:

1. A method, comprising:

transmitting, by a network, an indication of availability of clock information;
receiving a request to provide information for at least one specific clock domain;

and

transmitting the information for the at least one specific clock domain according to a determined periodicity of time reference information signaling for the at least one clock domain.

2. The method according to claim 1, further comprising receiving assistance information allowing the network to determine the periodicity of the time reference information signaling for the at least one clock domain.

3. The method according to claim 2, wherein the assistance information comprises at least one of an explicit indication of the preferred periodicity, an indication of synchronization accuracy requirements of applications, or an indication of synchronization accuracy requirements of the at least one clock domain.

4. The method according to claim 1, wherein the clock information comprises information about multiple clock domains.

5. The method according to claim 4, further comprising receiving time reference information for the multiple clock domains.

6. The method according to claim 5, wherein the time reference information comprises at least one of a full timing information for a clock from multiple domains, or a combination of full timing information for a single domain and frequency offset between a primary domain clock (PDC) and clocks of additional domains.

7. The method according to claim 1, further comprising determining the periodicity for transmission of the clock information based on at least one of the clock stability or the required clock precision.

8. The method according to claim 1, further comprising transmitting the clock information according to the indication of the availability of the clock information.

9. The method according to claim 1, wherein the transmitting of the clock information further comprises transmitting the clock information to user equipment via broadcast or unicast radio transmission.

10. The method according to claim 1, wherein the transmitting of the indication further comprises indicating whether a certain clock domain is currently signaled via system information block (SIB) and with which periodicity.

11. The method according to claim 1, further comprising deciding whether to provide the clock information with at least one of a periodic broadcast transmission, a unicast transmission to specific user equipment, or not provide a time reference for a certain clock domain at all but signal its availability in the network.

12. The method according to claim 1, wherein the clock information comprises at least one of an identifier, a class, an epoch, a timescale, a precision, a stability, a periodicity for transmission and a radio resource for the clock information.

13. An apparatus, comprising:

at least one processor; and

at least one memory comprising computer program code,

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

transmit an indication of availability of clock information;

receive, from a user equipment, a request to provide information for at least one specific clock domain; and

transmit, to the user equipment, the information for the at least one specific clock domain according to a determined periodicity of time reference information signaling for the at least one clock domain.

14. The apparatus according to claim 13, wherein the at least one memory and computer program code are further configured, with the at least one processor, to cause the apparatus at

least to receive assistance information allowing the network to determine the periodicity of the time reference information signaling for the at least one clock domain.

15. The apparatus according to claim 14, wherein the assistance information comprises at least one of an explicit indication of the preferred periodicity, an indication of synchronization accuracy requirements of applications, or an indication of synchronization accuracy requirements of the at least one clock domain.

16. The apparatus according to claim 13, wherein the clock information comprises information about multiple clock domains.

17. The apparatus according to claim 16, wherein the at least one memory and computer program code are further configured, with the at least one processor, to cause the apparatus at least to receive time reference information for the multiple clock domains.

18. The apparatus according to claim 13, wherein the time reference information comprises at least one of a full timing information for a clock from multiple domains, or a combination of full timing information for a single domain and frequency offset between a primary domain clock (PDC) and clocks of additional domains.

19. The apparatus according to claim 13, wherein the at least one memory and computer program code are further configured, with the at least one processor, to cause the apparatus at least to determine the periodicity for transmission of the clock information based on at least one of the stability or the precision.

20. The apparatus according to claim 13, wherein the at least one memory and computer program code are further configured, with the at least one processor, to cause the apparatus at least to transmit the clock information according to the indication of the availability of the clock information.

21. The apparatus according to claim 20, wherein the at least one memory and computer program code are further configured, with the at least one processor, to cause the apparatus at least to transmit the clock information to user equipment via broadcast or unicast radio transmission.

22. The apparatus according to claim 13, wherein the at least one memory and computer program code are further configured, with the at least one processor, to cause the apparatus at least to indicate whether a certain clock domain is currently signaled via system information block (SIB) and with which periodicity.

23. The apparatus according to claim 13, wherein the at least one memory and computer program code are further configured, with the at least one processor, to cause the apparatus at least to decide whether to provide the clock information with at least one of a periodic broadcast transmission, a unicast transmission to specific user equipment, or not provide a time reference for a certain clock domain at all but signal its availability in the network.

24. The apparatus according to claim 13, wherein the clock information comprises at least one of an identifier, a class, an epoch, a timescale, a precision, a stability, a periodicity for transmission and a radio resource for the clock information.

25. A method, comprising:

receiving, at a user equipment associated with a network, an indication of availability of clock information from the network;

requesting information for at least one clock domain from the network; and

receiving, from the network, the information for the at least one clock domain according to a determined periodicity.

26. The method according to claim 25, wherein the requesting further comprises transmitting, to the network, assistance information allowing the network to determine a preferred periodicity of time reference information signaling for the at least one clock domain.

27. The method according to claim 26, wherein the assistance information comprises at least one of an explicit indication of the preferred periodicity, an indication of synchronization accuracy requirements of applications, or an indication of synchronization accuracy requirements of the at least one clock domain.

28. The method according to claim 25, wherein the requesting comprises transmitting a

request for the information for the at least one clock domain via at least one of a unicast radio resource control message, a physical random access channel preamble, an indication in a system information request message, or user equipment assistance information.

29. The method according to claim 26, wherein the transmitting of the assistance information comprises at least one of:

transmitting the assistance information comprising an explicit indication of the preferred periodicity of the time reference information signaling for the at least one clock domain; or

transmitting a synchronization accuracy requirement for the at least one clock domain to allow the preferred periodicity to be determined by the network.

30. The method according to claim 25, wherein the clock information comprises at least one of an identifier, a class, an epoch, a timescale, a precision, a stability, a periodicity for transmission and a radio resource for the clock information.

31. The method according to claim 25, wherein the clock information comprises information about multiple clock domains.

32. The method according to claim 25, wherein the receiving of the information for the at least one clock domain further comprises receiving the information from the network via broadcast or unicast radio transmission in at least one of separate SIBs, separate SI messages, a single SIB, or a single SI message.

33. The method according to claim 25, wherein the receiving of the indication further comprises receiving an indication of whether a certain clock domain is currently signaled via system information block (SIB) and with which periodicity.

34. An apparatus, comprising:

at least one processor; and

at least one memory comprising computer program code,

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

receive an indication of availability of clock information from a network;

request information for at least one clock domain from the network; and
receive, from the network, the information for the at least one clock domain according to a determined periodicity.

35. The apparatus according to claim 34, wherein the at least one memory and computer program code are further configured, with the at least one processor, to cause the apparatus at least to transmit, to the network, assistance information allowing the network to determine a preferred periodicity of time reference information signaling for the at least one clock domain.

36. The apparatus according to claim 35, wherein the assistance information comprises at least one of an explicit indication of the preferred periodicity, an indication of synchronization accuracy requirements of applications, or an indication of synchronization accuracy requirements of the at least one clock domain.

37. The apparatus according to claim 34, wherein the at least one memory and computer program code are further configured, with the at least one processor, to cause the apparatus at least to transmit a request for the information for the at least one clock domain via at least one of a unicast radio resource control message, a physical random access channel preamble, an indication in a system information request message, or user equipment assistance information.

38. The apparatus according to claim 35, wherein the at least one memory and computer program code are further configured, with the at least one processor, to cause the apparatus at least to:

transmit the assistance information comprising an explicit indication of the preferred periodicity of the time reference information signaling for the at least one clock domain; or

transmit a synchronization accuracy requirement for the at least one clock domain to allow the preferred periodicity to be determined by the network.

39. The apparatus according to claim 34, wherein the clock information comprises at least one of an identifier, a class, an epoch, a timescale, a precision, a stability, a periodicity for transmission or a radio resource for the clock information.

40. The apparatus according to claim 34, wherein the clock information comprises information about multiple clock domains.

41. The apparatus according to claim 34, wherein the at least one memory and computer program code are further configured, with the at least one processor, to cause the apparatus at least to receive the information for the at least one clock domain from the network via broadcast or unicast radio transmission in at least one of separate SIBs, separate SI messages, a single SIB, or a single SI message.

42. The apparatus according to claim 34, wherein the at least one memory and computer program code are further configured, with the at least one processor, to cause the apparatus at least to receive an indication of whether a certain clock domain is currently signaled via system information block (SIB) and with which periodicity.

43. A non-transitory computer readable medium comprising program instructions stored thereon for performing at least the following:

- receiving an indication of availability of clock information from a network;
- requesting information for at least one clock domain from the network; and
- receiving, from the network, the information for the at least one clock domain according to a determined periodicity.

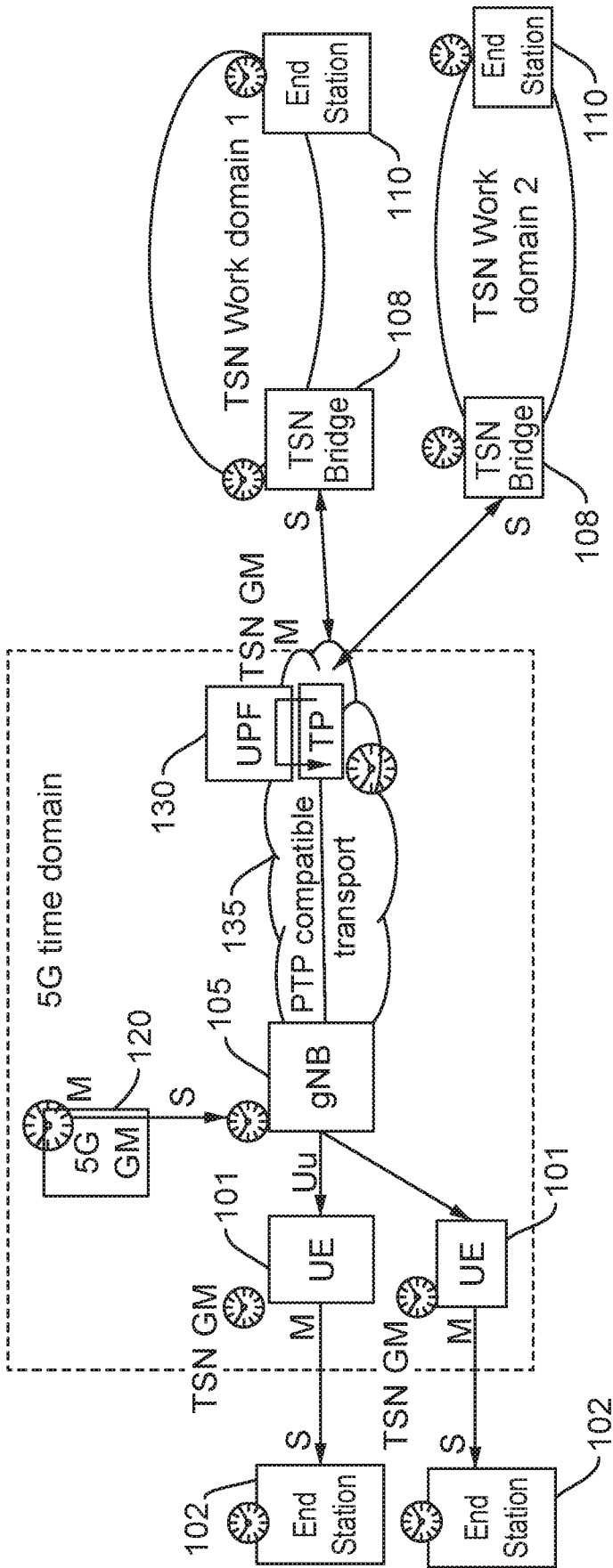


Fig. 1

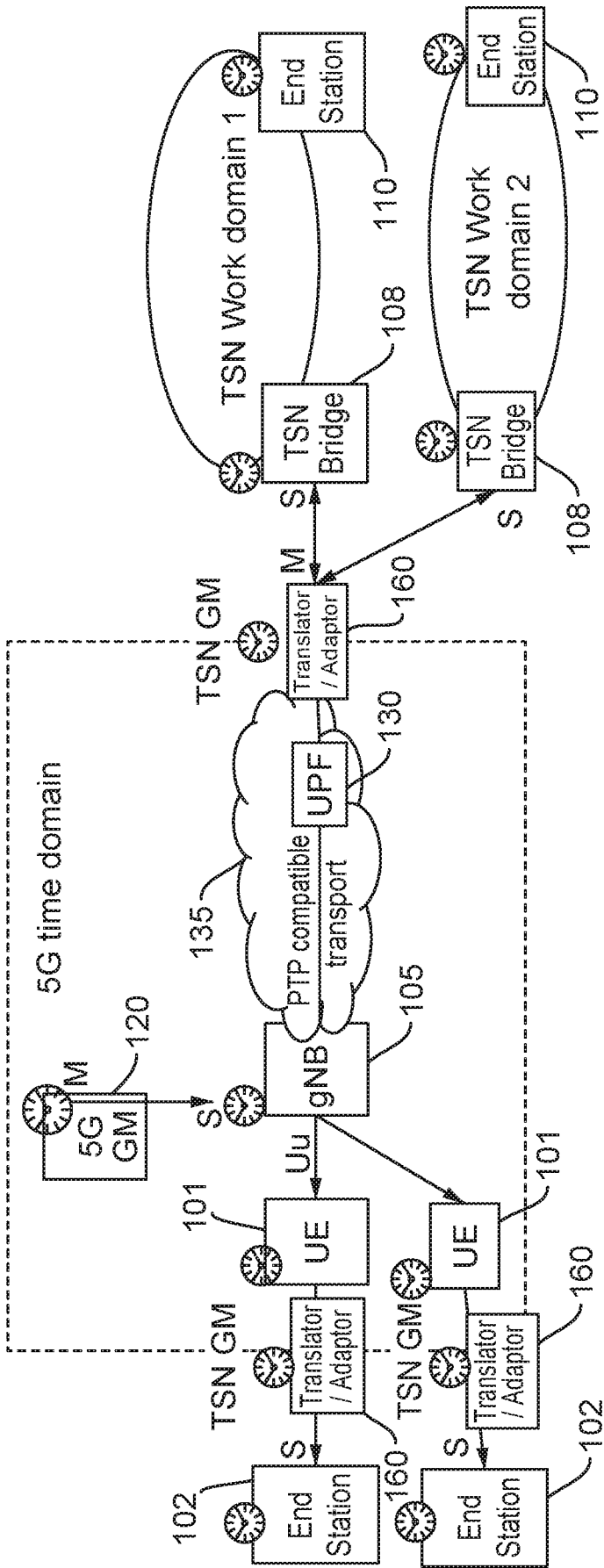


Fig. 2

3/7

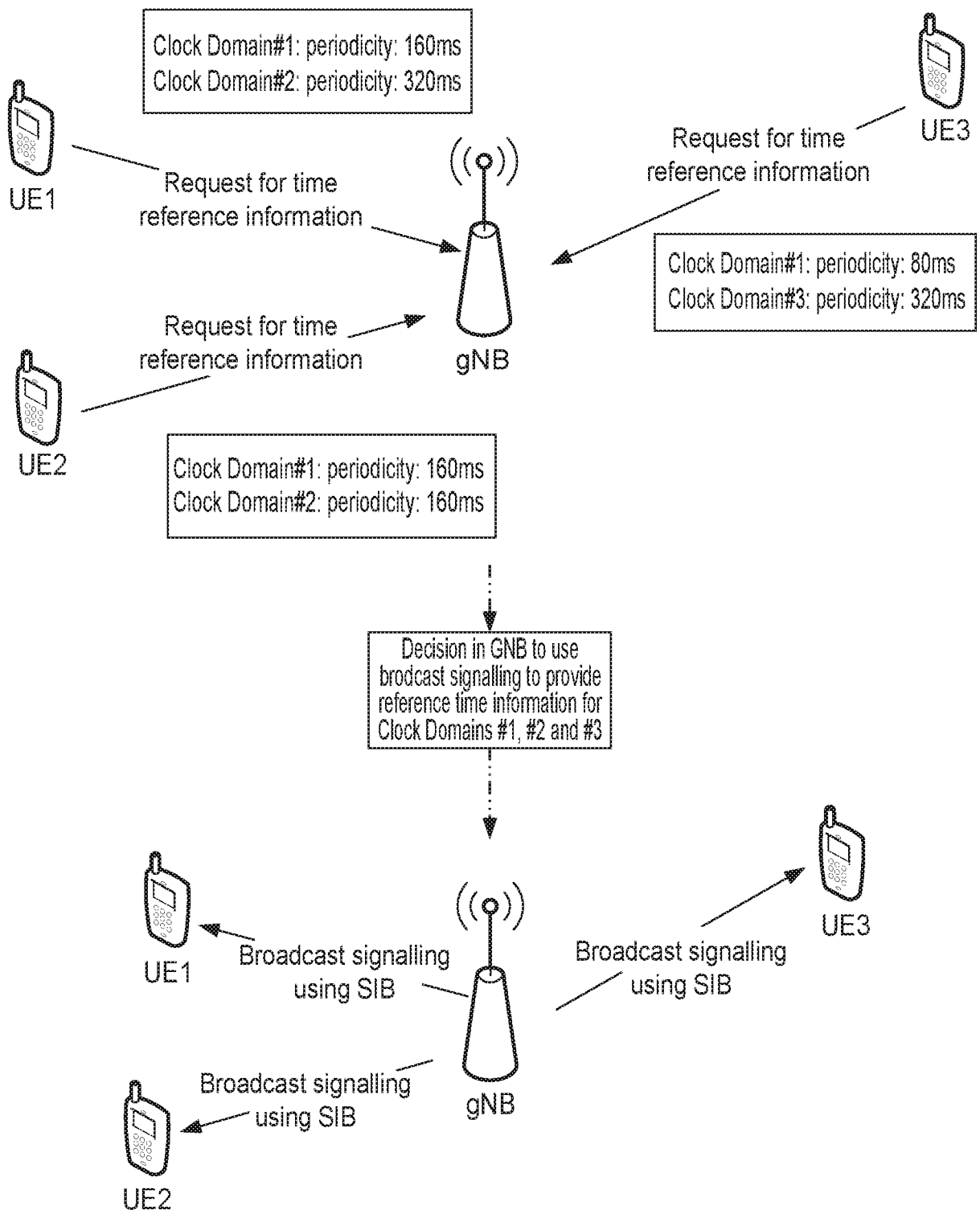


Fig. 3

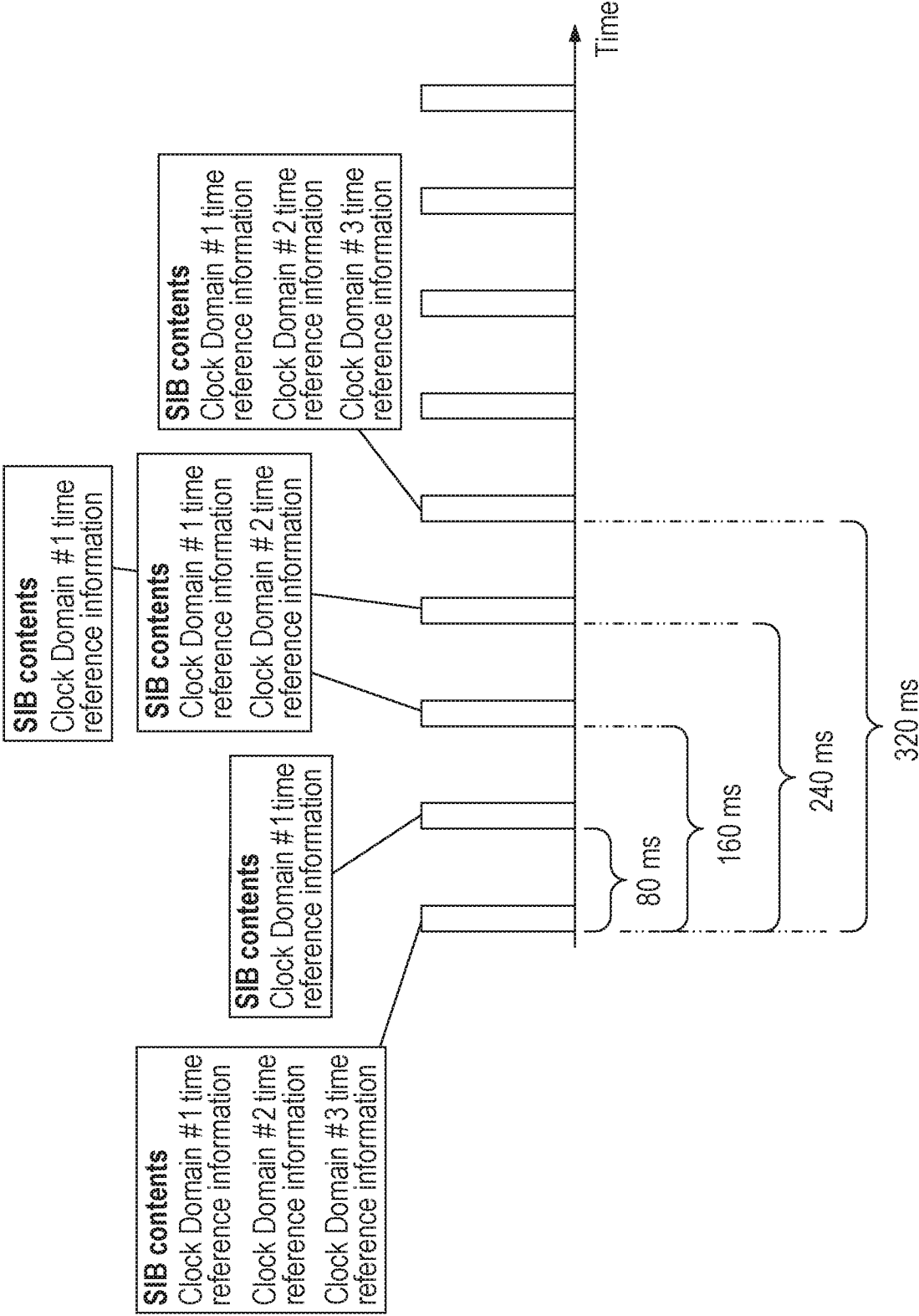


Fig. 4

5/7

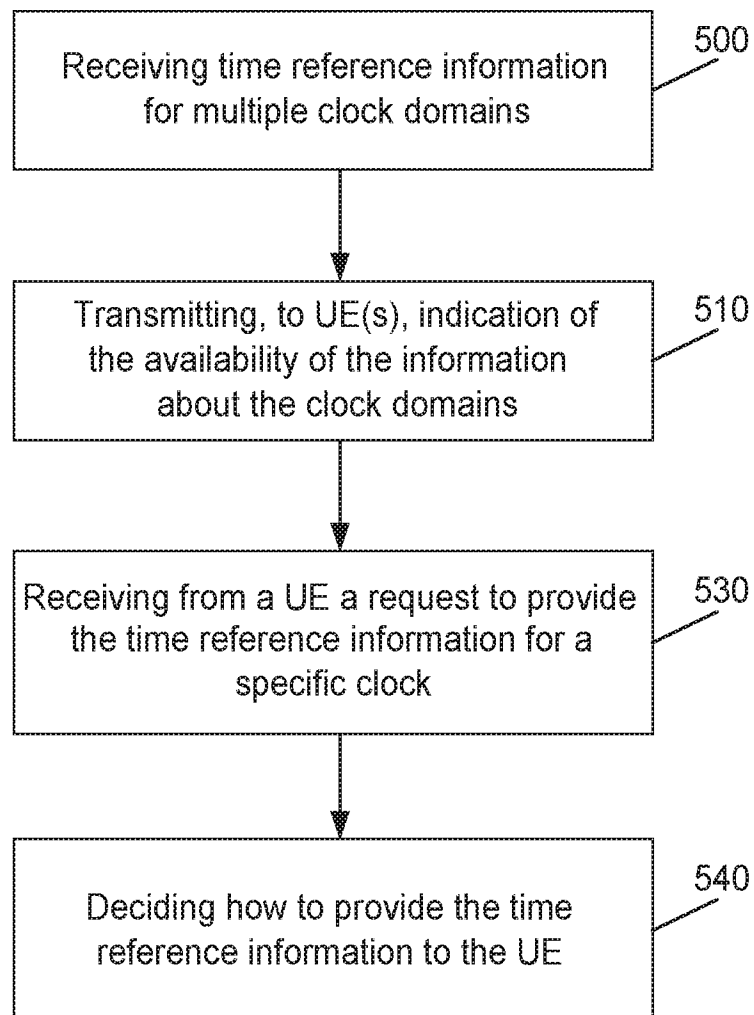


Fig. 5a

6/7

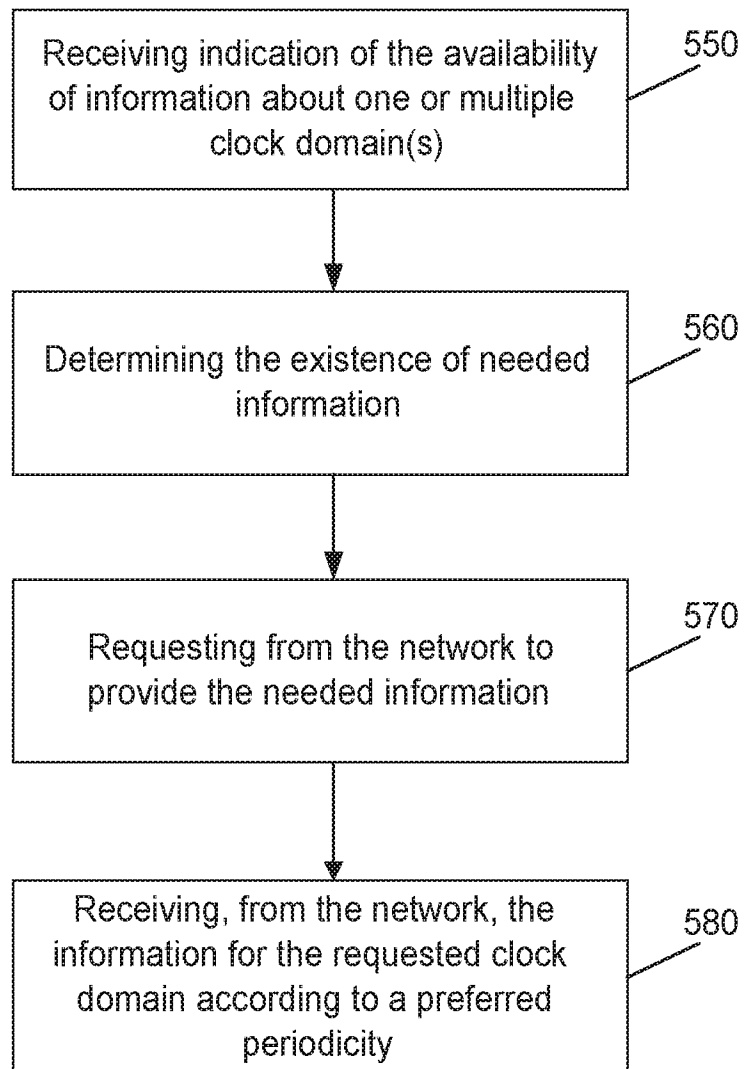


Fig. 5b

7/7

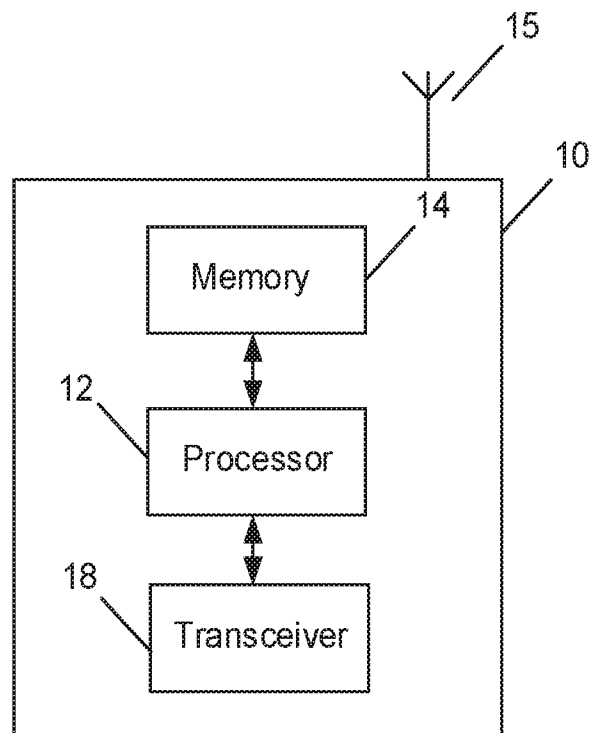


Fig. 6a

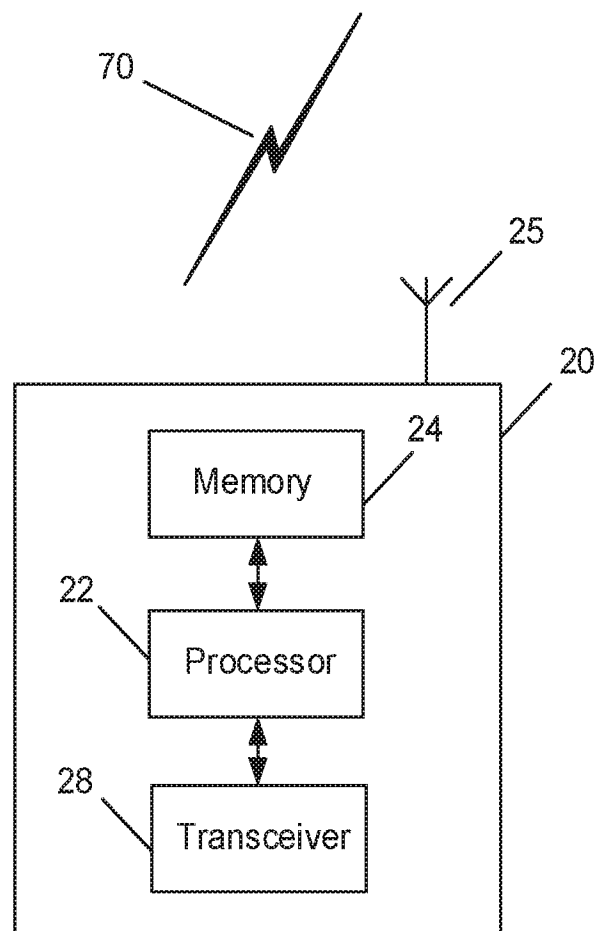


Fig. 6b

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/051986

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04J3/06 H04W48/14
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04J H04W

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2018/203633 A1 (LG ELECTRONICS INC [KR]) 8 November 2018 (2018-11-08) paragraph [0005] paragraph [0010] paragraph [0029] - paragraph [0030] paragraph [0057] paragraph [0064] figures 8-10 ----- -/--	1-43



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

5 June 2020

Date of mailing of the international search report

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Authorized officer

Marongiu, M

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/051986

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	NOKIA ET AL: "Support for Clock Synchronization Service", 3GPP DRAFT; R2-1900633 SUPPORT FOR CLOCK SYNCHRONIZATION SERVICE, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANC , vol. RAN WG2, no. Athens, Greece; 20190225 - 20190301 14 February 2019 (2019-02-14), XP051602011, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg%5Fran/WG2%5FRL2/TSGR2%5F105/Docs/R2%2D1900633%2Ezip [retrieved on 2019-02-14] the whole document -----	1-43
A	QUALCOMM INCORPORATED: "Discussion SA2 LS on RAN Impact analysis due to TSN", 3GPP DRAFT; R1-1900869 DISCUSSION SA2 LS ON RAN IMPACT ANALYSIS DUE TO TSN, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CED , vol. RAN WG1, no. Taipei, Taiwan; 20190121 - 20190125 20 January 2019 (2019-01-20), XP051593715, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings%5F3GP%5FSYNC/RAN1/Docs/R1%2D1900869%2Ezip [retrieved on 2019-01-20] the whole document -----	1-42

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2020/051986

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2018203633	A1	08-11-2018	NONE
