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(54) **Title:** APPARATUSES AND METHODS TO REDUCE APPLICATION LATENCY FOR PERIODIC DATA TRANSMISSION IN RADIO ACCESS NETWORKS

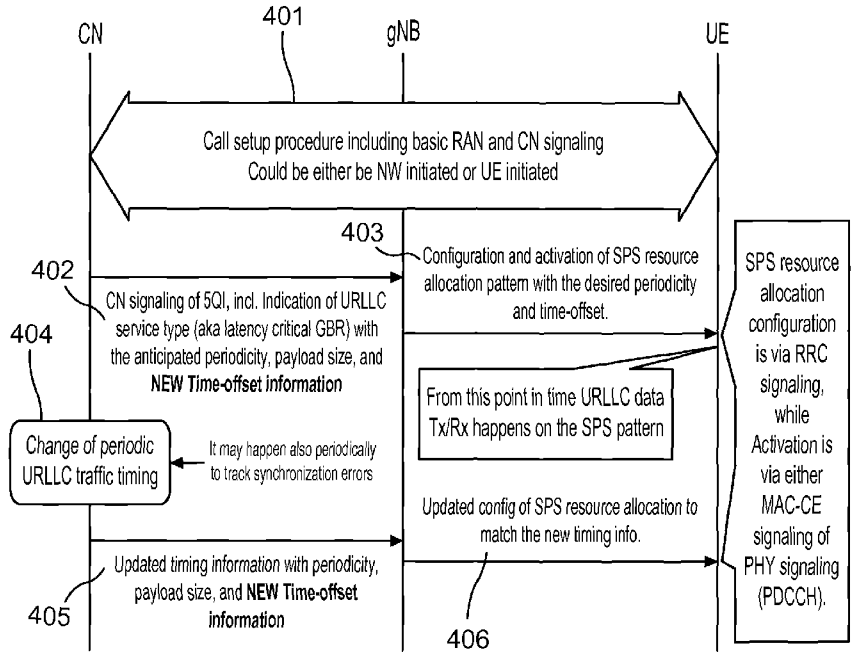


Fig. 4

(57) **Abstract:** Systems, methods, apparatuses, and computer program products for reducing application latency in radio access networks are provided. One example method may include computing periodicity and time offset information for an application or service, and a core network node signaling a service type, the periodicity, and the time offset information to a network node, such as a gNB.

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TITLE:

# APPARATUSES AND METHODS TO REDUCE APPLICATION LATENCY FOR PERIODIC DATA TRANSMISSION IN RADIO ACCESS NETWORKS

## FIELD:

**[0001]** Some example embodiments may generally relate to mobile or wireless telecommunication systems. For instance, various example embodiments may relate to reducing application latency in such telecommunication systems.

## 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), LTE-A Pro, and/or fifth generation (5G) radio access technology or new radio (NR) access technology. Fifth generation (5G) or new radio (NR) wireless systems refer to the next generation (NG) of radio systems and network architecture. It is estimated that NR will provide bitrates on the order of 10-20 Gbit/s or higher, and will support at least enhanced mobile broadband (eMBB) and ultra-reliable low-latency-communication (URLLC). 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 or NR, the nodes that can provide radio access functionality to a user equipment (i.e., similar to Node B in E-UTRAN or eNB in LTE) may be referred to as a next generation or 5G Node B (gNB).

SUMMARY:

**[0003]** One example embodiment is directed to a method, which may include computing periodicity and time offset information of an application or service, and signaling, by a core network, a service type, the periodicity, and the time-offset information to a new radio (NR) node.

**[0004]** Another example embodiment is directed to an apparatus including 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 compute periodicity and time offset information of an application or service, and to signal a service type, the periodicity, and the time-offset information to a new radio (NR) node.

**[0005]** Another example embodiment is directed to an apparatus that may include computing means for computing periodicity and time offset information of an application or service, and signaling means for signaling a service type, the periodicity, and the time-offset information to a new radio (NR) node.

**[0006]** Another example embodiment is directed to a non-transitory computer readable medium comprising program instructions stored thereon for computing periodicity and time offset information of an application or service, and for signaling a service type, the periodicity, and the time-offset information to a new radio (NR) node.

**[0007]** Another example embodiment is directed to a method, which may include receiving, from a core network, an indication of a service type, periodicity, and time-offset information of an application or service. The method may also include configuring, by a new radio (NR) node, a semi-persistent scheduling (SPS) resource allocation to be in coherence with the received service type, periodicity, and time-offset information.

**[0008]** Another example embodiment is directed to an apparatus including 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, from a core network, an indication of a service type, periodicity, and time-offset information of an application or service, and to configure a semi-persistent scheduling (SPS) resource allocation to be in coherence with the received service type, periodicity, and time-offset information.

**[0009]** Another example embodiment is directed to an apparatus, which may include receiving means for receiving, from a core network, an indication of a service type, periodicity, and time-offset information of an application or service, and configuring means for configuring a semi-persistent scheduling (SPS) resource allocation to be in coherence with the received service type, periodicity, and time-offset information.

**[0010]** Another example embodiment is directed to a non-transitory computer readable medium comprising program instructions stored thereon for receiving, from a core network, an indication of a service type, periodicity, and time-offset information of an application or service, and for configuring a semi-persistent scheduling (SPS) resource allocation to be in coherence with the received service type, periodicity, and time-offset information.

## BRIEF DESCRIPTION OF THE DRAWINGS:

**[0011]** For proper understanding of example embodiments, reference should be made to the accompanying drawings, wherein:

**[0012]** Fig. 1 illustrates a diagram depicting an example of unsynchronized data arrival, according to an embodiment;

**[0013]** Fig. 2 illustrates a diagram depicting an example of synchronized data arrival, according to an embodiment;

**[0014]** Fig. 3 illustrates a diagram an example of offset reporting and resource allocation, according to an embodiment;

**[0015]** Fig. 4 illustrates an example of a signaling diagram, according to an embodiment;

**[0016]** Fig. 5a illustrates an example block diagram of an apparatus, according to one embodiment;

**[0017]** Fig. 5b illustrates an example block diagram of an apparatus, according to another embodiment;

**[0018]** Fig. 6a illustrates an example flow diagram of a method, according to one embodiment; and

**[0019]** Fig. 6b illustrates an example flow diagram of a method, according to another embodiment.

DETAILED DESCRIPTION:

**[0020]** 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 reducing application latency in radio access networks, such as NR, as represented in the attached figures and described below, is not intended to limit the scope of certain embodiments but is representative of selected example embodiments.

**[0021]** The features, structures, or characteristics of example embodiments described throughout this specification may be combined in any suitable manner in one or more 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 embodiments.

**[0022]** 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.

**[0023]** Certain example embodiments may relate to new radio (NR) user-plane (U-plane) layers, and may deal with concepts related to semi-persistent scheduling (SPS), persistent scheduling (PS), medium access control (MAC) scheduling, 5G quality of service (QoS) class identifier (5QCI), as well as related protocol layers such as service data adaptation protocol (SDAP), packet data convergence protocol (PDCP). Some example embodiments may utilize a control plane protocol, such as radio resource control (RRC).

**[0024]** Some example embodiments may specifically relate to Ultra-Reliable Low-Latency Communications (URLLC), for example with respect to applications delivering data that have periodic behavior and strong reliability/latency requirements, such as industrial control loops, autonomous driving, remote surgery and so on. Thus, new Radio (NR) ongoing standardization includes investigating communications dedicated to critical applications, e.g., autonomous driving, remote surgery, industrial automation, etc. URLLC may be needed to support these types of applications, demanding a successful and reliable packet transmission with challenging RAN latency, for example, down to 0.5 ms with reliability of $r = 1 - 10^{-x}$, where $x \geq 5$.

**[0025]** URLLC may be challenging to deliver, especially when the latency budget is in the order of a single millisecond (ms). However, in the case of traffic types with periodic behavior, for example with constant packet arrival every $T = 5\ \mathrm{ms}$, information about the periodicity may be used to reduce URLLC challenges. Pre-allocating resources, with dynamic packet scheduling (PS) or semi-persistent scheduling (SPS), to the UE carrying the periodic traffic may allow for a reduction in the delay of the scheduling request procedure for UL operations, requiring at least 0.57 ms even assuming the ideal 3GPP SR Delay model.

**[0026]** However, application delay may be experienced due to unsynchronized data arrival in the gNB transmission buffer and the allocated resources for the UE. Fig. 1 illustrates an example of unsynchronized data arrival (vertical arrows) and corresponding UE's allocated resources. The random delay depends on the synchronization error $\Delta$, and can assume values up to $T$. In the example of Fig. 1, the time error $\Delta$ in the unsynchronized scenario is introducing a delay in the application latency budget, and it may be assumed that it is uniformly distributed over the interval $[0, T]$. Since, with URLLC, one of the goals is the reliability in successfully transmitting a packet within a latency budget, it is worth to evaluate the quantile function for the probability distribution function of $\Delta$ with reliability $r$, $q_{\Delta}(r) = rT \approx T$, if the desired $r$ is close to 1.

**[0027]** Without synchronizing the PS/SPS scheduler resource allocations to the UE with the data arrival, an undesirable application delay is introduced in the system, and it could dominate the performance of URLLC service. RAN standards are being designed to achieve a latency of 0.5/1 ms; however, these benefits can be dominated by this application delay, which can assume values in the order of milliseconds.

**[0028]** For each UE, at least one packet session is established. One or more QoS flows are associated to an end-to-end (E2E) session. The 5G RAN may associate the QoS flows with the data radio bearers (DRBs), and this is conducted at the Service Data Adaptation Protocol (SDAP) protocol layer in the gNB. This mapping may be based on 5G QoS class indices (5QI) in the transport header of the packets, and on corresponding QoS parameters, which are signalled via core network (CN) interface when a packet session is established. The 5QI (as defined in 3GPP TS 23.501) contains a set of default QoS parameters for a large number of services, covering various eMBB, URLLC, and mMTC use cases. The QoS parameters in the 5QI table may include resource type (GBR, delay critical GBR, and non-GBR), priority, packet delay budget, packet error rate, and averaging window. Also, it is proposed to include information such expected packet inter arrival times and maximum packet size information for services where this is useful. Some of the entries in the 5QI table are expected to correspond to periodic URLLC application, where data packets come at a fixed regular rate. But, in the current standardization discussions in SA2 / RAN2, the time-reference for the arrival of such regular packet arrival has not been discussed.

**[0029]** NR is expected to include support for SPS. The SPS for NR may roughly be in line with SPS defined for LTE. Thus, RRC signalling may be used for configuration of the regular resource allocation for each user (aka the SPS resource allocation pattern). The SPS resource allocation pattern can be dynamically activated/de-activated by means of either MAC-CE or PHY-layer control signalling. Related hybrid automatic repeat request (HARQ) retransmissions may be dynamically scheduled, i.e., using dynamic scheduling grants sent on the physical downlink control channel (PDCCH). More information can be found in the 3GPP NR Stage-2 and MAC specifications in 3GPP TS 38.300 and 3GPP TS 38.331, respectively.

**[0030]** However, it is noted that the current 3GPP NR standards agreements, offer no information for the gNB (RRC/MAC) on what is best time-offset for configuration of the SPS resource allocation pattern to minimize the application delay Δ discussed above. Additionally, there is no mention about synchronization information (time-offset) between the application data and the SPS resources to be scheduled; hence, there is currently no solution for reducing the values that could be assumed by $\Delta$, uniformly distributed over the interval $[0,T]$. Certain embodiments, therefore, address and overcome at least these problems.

**[0031]** Certain example embodiments may be designed to allow the reduction of the application delay due to $\Delta$, achieving a smaller delay $\delta$ implementing a synchronized scheme, as graphically depicted in the example of Fig. 2. More specifically, Fig. 2 illustrates an example of synchronized data arrival (vertical arrows) and corresponding DRB's allocated resources. The safety margin $\epsilon \ll T$ may take into account the possible realization of jitter and synchronization drifts.

**[0032]** One example embodiment provides that, for URLLC latency critical guaranteed bit rate (GBR) services with periodic packet arrival, the CN should be able to signal the time-offset of when such data arrives at the gNB. In an embodiment, signaling of periodicity (i.e., inter-arrival time) and signaling of (maximum) packet size may already be covered by the current SA2/RAN2 agreements for NR. According to an embodiment, time-offset values are signaled, e.g., by the CN, and the time-offset value may contain information about the absolute arrival time of a packet belonging to the periodic allocation, as will be discussed in more detail below.

**[0033]** In some example embodiments, the above mentioned information— i.e., periodicity, maximum packet size, and time-offset values— may be made available for the RRC entity in the gNB, so it can configure the SPS resource allocation to be in coherence with the periodical packet arrival. Therefore, unnecessary delays from packet queuing in the gNB, where packets are queued while waiting for the next available SPS resource allocation opportunity, can be minimized. According to an embodiment, the resulting allocation of the SPS resources may be communicated to the UE and the lower layers. In one embodiment, slow periodical updates (e.g., every 10s, or after 100-1000 transmissions) may be communicated (e.g., to the RRC), from the core network, about the evolution of the parameters P (periodicity, maximum packet size, and time-offset values), to eventually update the SPS allocation. As it is done during the first allocation phase, in an embodiment, P may be shared with the layer handling SPS to correct errors or drifts due to errors in synchronization or time drifts due to errors in the arrival periodicity.

**[0034]** By implementing certain example embodiments described herein, the periodic application data may be synchronized with the periodic resource allocation, allowing to reduce the application delay budget from $\Delta$ to a margin $\epsilon \ll \Delta$, as one can see by comparing Fig. 1 and Fig. 2. Fig. 4 illustrates an example signaling diagram according to certain example embodiments. As a result of the signaling depicted in the example of Fig. 4, a synchronized URLLC transmission can be quickly and reliably setup from the first transmission instant. It is noted that the term $\epsilon > 0$ may depend on a computed safety margin to compensate for possible jitters in the application periodical data generation and drifts due to incorrect periodicity, as well as on the realization of these random quantities. As one example, while $\Delta$ could be in the order of magnitude of milliseconds, it is possible that $\epsilon$ will be in the order of 10-20 microseconds, maybe lower, depending on the application and the frequency of the periodical updates. As a result of these updates, the offset can be continuously updated and tracked, correcting jitters and drifts errors, and allowing to keep small the term $\epsilon$.

**[0035]** Returning to the example of Fig. 4, at 401, a call setup procedure may be executed including basic RAN and CN signaling, which can be either network-initiated or UE-initiated. In an embodiment, the CN may signal to a gNB, at 402, 5QCI including an indication of URLLC service type (latency critical GBR) along with the anticipated periodicity, payload size, and/or time offset information. At 403, the gNB may signal, to a UE, configuration and activation of SPS resource allocation pattern with the desired periodicity and/or time offset information. There may be a change of periodic URLLC traffic timing, at 404. When such a change occurs, the CN may signal to the gNB, at 405, updated timing information with updated periodicity, updated payload size, and updated time offset information. The gNB may then, at 406, signal updated configuration of SPS resource allocation to match the new timing information. In an embodiment, the SPS resource allocation configuration may be via RRC signaling, while activation may be via MAC-CE signaling or PHY signaling (PDCCH), for example.

**[0036]** As depicted in Fig. 4, certain example embodiments include the signaling of time-offset values and periodicity and, therefore, one embodiment may include computing the application offset and periodicity. For periodic packet transmission, the arrival time of the $k$-th packet may be modelled as: $t_k = T_0 + kT + \delta + n_k$, where $T_0$ is a starting time reference point, $T$ the arrival periodicity, $\delta$ the offset of the first packet allocation (counting ID from zero) with respect to $T_0$, and $n_k$ an error term taking into account all jitter and timing drifts.

**[0037]** According to an embodiment, it may be assumed that every time an update comes to the layer handling SPS (likely the RRC), new values are set for $T_0$, $T$, $\delta$ and the counter $k$ starts again from 0. In certain example embodiments, $T_0$ may be set corresponding to the beginning of the actual hyper frame number (HFN), and $T$ and $\delta$ may be updated accordingly.

**[0038]** According to some example embodiments, the application offset $\delta$, as well as the periodicity $T$, may be tracked considering the time when the data are estimated to arrive in the MAC transmission buffer. Hence, certain example embodiments may be configured to compute the application data generation periodicity and its offset, and the time spent in the stack, adding all headers down to the MAC layer packet.

**[0039]** While the periodicity T may be already determined by the application data generation periodicity, the final offset $\delta$ may take into account application raw offset $\delta'$ and the delay $d$ due to all the processing before the packets arrives to the transmission buffer (we can assume a constant) $\gamma$. Since packet arrivals may also experience jitter and drifts, due to the application, synchronization errors or different clock frequency, certain embodiments may compensate by adding a term $c$ that takes into account all these sources of timing errors, such that the margin $\epsilon$ between the packet arrival in the buffer and the allocated resources is always large enough to guarantee that that packet can be transmitted in its reserved resource slot. Hence, in an embodiment, the offset may be computed as: $\delta = \delta' + d + c$. It is noted that $\epsilon = d + c - n_k$.

**[0040]** According to certain example embodiments, the application offset can be shared or signaled, for example as shown in steps 402 and 405 of Fig. 4, with the same messages handling the periodicity information. Thus, in an embodiment, the protocols handling the periodicity information may be changed to have a new field for communicating the offset $\delta$. As depicted in Fig. 4, this information may be signaled from the CN to the gNB.

**[0041]** When the SDAP maps the periodical traffic flow to a certain QoS flow and DRB, the QoS metric (including 5QCI) may then include the time-offset information, as well as optionally including the periodicity and packet size of the traffic. It is noted that this messaging (e.g., as shown in Fig. 4) allows certain example embodiments to work with the same message format both in case of a “new” DRB asking for SPS (e.g., a new connected user), and a status “update” of an already existing DRB (to keep track of the synchronization of an active user).

**[0042]** Fig. 3 illustrates an example of offset $\delta$ reporting and resource allocation, according to the message flow of certain example embodiments. In some example embodiments, the offset message may be composed of two fields, SPSOffset_SFN and SPSOffset_QTI. SPSOffset_SFN may include the System Frame Number (SFN) where the value belongs (10 bits). Since the SFN lasts 10240 ms, another value may be used to achieve higher precision in some example embodiments. SPSOffset_QTI may include an index related to a uniformly quantized time index in a SFN duration (L bits → values from $0, 1, \ldots, 2^L - 1$ ). If the computed offset with respect to the reference $T_0$ is quantized— rounding up— in SFN=SPSOffset_SFN and QTI=SPSOffset_QTI. Then, in one embodiment, based on the packet dimension and the chosen MCS (or just the amount of demanded resources), the SPS may allocate the resources to the UE to the first transmission chance after the quantized offset reported, as well as replicating this allocation with periodicity *T*, until any status update message comes into the system.

**[0043]** According to certain example embodiments, the offset $\delta$ may then be computed as: $\delta = \text{SPSOffset\_SFN} + 2^{-L} \cdot \text{SPSOffset\_Offset}$. It is noted that in case of status "update", the offset may be related to the first packet that will come in the buffer, or the previously received packet. In an embodiment, all the future allocations may be computed based on the values of $\delta$ and $T$ and the SPS allocation may be updated accordingly, as seen in the example of Fig. 3. According to some example embodiments, the allocation may also concern resources in time before $T_0$, if the used reference $T_0$ is related to a future time stamp.

**[0044]** Since the offset and time modelling has the beginning of the actual Hyper Frame $T_0$ as time reference point, one embodiment may update the periodicity and offset (and other) information at least at the beginning of each Hyper Frame (for example every 10.24 seconds), but the update may happen more frequently if necessary according to other embodiments.

**[0045]** Fig. 5a illustrates an example of an apparatus 10 according to an embodiment. 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 node or server in a core network, such as a gateway or service and subscriber management node.

**[0046]** 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. 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. 5a.

**[0047]** As illustrated in the example of Fig. 5a, 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. 5a, 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 example embodiments, the multiprocessor system may be tightly coupled or loosely coupled (e.g., to form a computer cluster).

**[0048]** 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.

**[0049]** 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 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 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.

**[0050]** 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 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.

**[0051]** In some example 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 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 LTE, 5G, NR, BT-LE, NFC, radio frequency identifier (RFID), 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).

**[0052]** 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 example embodiments, transceiver 18 may be capable of transmitting and receiving signals or data directly. Additionally or alternatively, in some example embodiments, apparatus 10 may include an input and/or output device (I/O device).

**[0053]** 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.

**[0054]** According to some example 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 example embodiments, transceiver 18 may be included in or may form a part of transceiving circuitry.

**[0055]** 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.

**[0056]** As introduced above, in certain example embodiments, apparatus 10 may be a core network node or gateway, or the like. According to certain example embodiments, apparatus 10 may be controlled by memory 14 and processor 12 to perform the functions associated with any of the example embodiments described herein, such as the flow, signaling or block diagrams illustrated in Figs. 1-4. For example, in certain example embodiments, apparatus 10 may be controlled by memory 14 and processor 12 to perform one or more of the steps performed by the CN illustrated in Fig. 4. In certain example embodiments, apparatus 10 may be configured to perform a process for reducing application latency

**[0057]** For instance, in some example embodiments, apparatus 10 may be controlled by memory 14 and processor 12 to compute at least an application time-offset and periodicity of an application or service. In some example embodiments, the application or service may be an application or service that requires URLLC. In an embodiment, for periodic packet transmission, apparatus 10 may be controlled by memory 14 and processor 12 to model the arrival time of the $k$-th packet as: $t_k = T_0 + kT + \delta + n_k$, where $T_0$ is a starting time reference point, $T$ the arrival periodicity, $\delta$ the offset of the first packet allocation (counting ID from zero) with respect to $T_0$, and $n_k$ an error term taking into account all jitter and timing drifts. According to some example embodiments, the application offset $\delta$, as well as the periodicity $T$, may be tracked considering the time when the data are estimated to arrive in the MAC transmission buffer. Hence, certain example embodiments may be configured to compute the application data generation periodicity and its offset, and the time spent in the stack, adding all headers down to the MAC layer packet.

**[0058]** In an embodiment, apparatus 10 may then be controlled by memory 14 and processor 12 to signal, for example to a gNB, an indicator (e.g., 5QCI) including an indication of at least one of a service type (latency critical GBR), the anticipated periodicity, payload size, and/or the time-offset information. According to an embodiment, the service type may be a URLLC service type. In some embodiments, there may subsequently be a change of periodic traffic timing (e.g., periodic URLLC traffic timing). When such a change occurs, apparatus 10 may be controlled by memory 14 and processor 12 to signal, to the gNB updated timing information with updated periodicity, updated payload size, and/or updated time offset information. According to an embodiment, it may be assumed that every time an update comes to the layer handling SPS (likely the RRC), new values are set for $T_0$, $T$, $\delta$ and the counter $k$ starts again from 0. In certain embodiments, $T_0$ may be set corresponding to the beginning of the actual hyper frame number (HFN), and $T$ and $\delta$ may be updated accordingly. Since the offset and time modelling has the beginning of the actual Hyper Frame

$T_0$ as time reference point, one embodiment may update the periodicity and time offset (and other) information at least at the beginning of each Hyper Frame (for example every 10.24 seconds), but the update may happen more frequently if necessary according to other example embodiments.

**[0059]** While the periodicity T may be already determined by the application data generation periodicity, the final offset $\delta$ may take into account application raw offset $\delta'$ and the delay $d$ due to all the processing before the packets arrives to the transmission buffer (we can assume a constant) $\gamma$. Since packet arrivals may also experience jitter and drifts, due to the application, synchronization errors or different clock frequency, apparatus 10 may be controlled by memory 14 and processor 12 to compensate by adding a term $c$ that takes into account all these sources of timing errors, such that the margin $\epsilon$ between the packet arrival in the buffer and the allocated resources is always large enough to guarantee that that packet can be transmitted in its reserved resource slot. Hence, in an embodiment, apparatus 10 may be controlled by memory 14 and processor 12 to compute the time-offset as: $\delta = \delta' + d + c$. It is noted that $\epsilon = d + c - n_k$.

**[0060]** In certain example embodiments, apparatus 10 may be controlled by memory 14 and processor 12 to signal the indicator to include an offset message that is composed of two fields, SPSOffset_SFN and SPSOffset_QTI. SPSOffset_SFN may include the System Frame Number where the value belongs (10 bits). Since the SFN lasts 10.24 ms, another value may be provided to achieve higher precision. SPSOffset_QTI may include an index related to a uniformly quantized time index in a SFN duration (L bits → values from $0, 1, \ldots, 2^L - 1$ ).

**[0061]** According to certain embodiments, apparatus 10 may be controlled by memory 14 and processor 12 to compute the offset $\delta$ as: $\delta = \text{SPSOffset\_SFN} + 2^{-L} \cdot \text{SPSOffset\_Offset}$. It is noted that in case of status "update", the offset may be related to the first packet that will come in the buffer, or the previously received packet. In an embodiment, all the future allocations may be computed based on the values of $\delta$ and $T$ and the SPS allocation may be updated accordingly, as seen in Fig. 3.

**[0062]** Fig. 5b illustrates an example of an apparatus 20 according to another embodiment. In an embodiment, apparatus 20 may be a node, host, or server in a communications network or serving such a network. For example, apparatus 20 may be a base station, a Node B, an evolved Node B (eNB), 5G Node B or access point, next generation Node B (NG-NB or gNB), associated with a radio access network, such as a GSM network, LTE network, 5G or NR. 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.

**[0063]** In some example embodiments, apparatus 20 may include one or more 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 LTE, LTE-A, NR, 5G, NFC, MulteFire, and/or any other 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. 5b.

**[0064]** As illustrated in the example of Fig. 5b, 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 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. 5b, multiple processors may be utilized according to other example embodiments. For 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 example embodiments, the multiprocessor system may be tightly coupled or loosely coupled (e.g., to form a computer cluster).

**[0065]** 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.

**[0066]** 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 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.

**[0067]** 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 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.

**[0068]** In some example 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 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 LTE, LTE-A, 5G, NR, BT-LE, NFC, RFID, UWB, and the like. The radio interface may 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.

**[0069]** For instance, transceiver 28 may be configured to modulate information on to a 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 example embodiments, transceiver 28 may be capable of transmitting and receiving signals or data directly. Additionally or alternatively, in some example embodiments, apparatus 10 may include an input and/or output device (I/O device). In certain example embodiments, apparatus 20 may further include a user interface, such as a graphical user interface or touchscreen.

**[0070]** 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 communications link 70 according to any radio access technology, such as NR.

**[0071]** According to some example 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 example embodiments, transceiver 28 may be included in or may form a part of transceiving circuitry.

**[0072]** As discussed above, according to some example embodiments, apparatus 20 may be a base station, node B, eNB, gNB, and/or next generation Node B (NG-NB), for example. According to certain example embodiments, apparatus 20 may be controlled by memory 24 and processor 22 to perform the functions associated with embodiments described herein. For example, in some example embodiments, apparatus 20 may be configured to perform one or more of the processes depicted in any of the flow charts or signaling diagrams described herein, such as the flow, signaling or block diagrams illustrated in Figs. 1-4.

**[0073]** According to some example embodiments, apparatus 20 may be controlled by memory 24 and processor 22 to receive, from the CN, an indicator (e.g., 5QCI) including an indication of at least one of a service type (latency critical GBR), the anticipated periodicity, payload size, and/or the time offset information. In certain example embodiments, the service type may be a URLLC service type. In one embodiment, apparatus 20 may then be controlled by memory 24 and processor 22 to signal, to a UE, configuration and activation of SPS resource allocation pattern with the service type, the desired periodicity and/or the time offset information as received from the CN. Subsequently, there may be a change of periodic traffic timing (e.g., periodic URLLC traffic timing) and, when such a change occurs, apparatus 20 may be controlled by memory 24 and processor 22 to receive, from the CN, updated timing information with updated periodicity, updated payload size, and/or updated time offset information. In an embodiment, apparatus 20 may then be controlled by memory 24 and processor 22 to signal updated configuration of SPS resource allocation to match the new timing information. In an embodiment, the SPS resource allocation configuration may be sent via RRC signaling, while activation may be via MAC-CE signaling or PHY signaling (PDCCH), for example.

**[0074]** Fig. 6a illustrates an example flow diagram of a method for reducing application latency, according to one embodiment. In certain example embodiments, the flow diagram of Fig. 6a may be performed by a core network node, such as a gateway or subscription server, for example. As illustrated in the example of Fig. 6a, the method may include, at 600, computing at least an application time-offset and periodicity of an application or service. For periodic packet transmission, the computing 600 may include modelling the arrival time of the $k$-th packet as: $t_k = T_0 + kT + \delta + n_k$, where $T_0$ is a starting time reference point, $T$ the arrival periodicity, $\delta$ the offset of the first packet allocation (counting ID from zero) with respect to $T_0$, and $n_k$ an error term taking into account all jitter and timing drifts. According to some embodiments, the application offset $\delta$, as well as the periodicity $T$, may be tracked considering the time when the data are estimated to arrive in the MAC transmission buffer. Hence, in certain example embodiments, the computing 600 may include computing the application data generation periodicity and its offset, and the time spent in the stack, adding all headers down to the MAC layer packet.

**[0075]** In an embodiment, the method may also include, at 610, signaling, for example to a gNB, an indicator (e.g., 5QCI) including an indication of at least one of a service type (latency critical GBR), the anticipated periodicity, payload size, and/or time-offset information. In some example embodiments, at 620, it may be determined whether there is a change of periodic traffic timing. When such a change of periodic traffic timing occurs, the method may include, at 630, signaling, to the gNB, updated timing information with updated periodicity, updated payload size, and/or updated time offset information. According to an embodiment, it may be assumed that every time an update comes to the layer handling SPS (likely the RRC), new values are set for $T_0$, $T$, $\delta$ and the counter $k$ starts again from 0. In certain embodiments, $T_0$ may be set corresponding to the beginning of the actual HFN, and $T$ and $\delta$ may be updated accordingly. Since the offset and time modelling has the beginning of the actual Hyper Frame $T_0$ as time reference point, one embodiment may update the periodicity and offset (and other) information at least at the beginning of each Hyper Frame (for example every 10.24 seconds), but the update may happen more frequently if necessary according to other embodiments.

**[0076]** While the periodicity T may be already determined by the application data generation periodicity, the final offset $\delta$ may take into account application raw offset $\delta'$ and the delay $d$ due to all the processing before the packets arrives to the transmission buffer (we can assume a constant) $\gamma$. Since packet arrivals may also experience jitter and drifts, due to the application, synchronization errors or different clock frequency, the method may include compensating by adding a term $c$ that takes into account all these sources of timing errors, such that the margin $\epsilon$ between the packet arrival in the buffer and the allocated resources is always large enough to guarantee that that packet can be transmitted in its reserved resource slot. Hence, in an embodiment, the computing 600 may include computing the time-offset as: $\delta = \delta' + d + c$. It is noted that $\epsilon = d + c - n_k$.

**[0077]** In certain example embodiments, the signaling 610, 620 may include signaling the indicator to include an offset message that is composed of two fields, SPSOffset_SFN and SPSOffset_QTI. SPSOffset_SFN may include the SFN where the value belongs (10 bits). Since the SFN lasts 10240 ms, another value may be provided to achieve higher precision. SPSOffset_QTI may include an index related to a uniformly quantized time index in a SFN duration (L bits → values from $0, 1, \ldots, 2^L - 1$). According to certain embodiments, the computing 600 may then include computing the offset $\delta$ as: $\delta = \text{SPSOffset\_SFN} + 2^{-L} \cdot \text{SPSOffset\_Offset}$.

**[0078]** Fig. 6b illustrates an example flow diagram of a method for non-linear precoding, according to one embodiment. In certain embodiments, the flow diagram of Fig. 6b may be performed by a network node, such as a base station, node B, eNB, gNB, or any other access node. As illustrated in the example of Fig. 6b, the method may include, at 650, receiving, from a CN node, an indicator (e.g., 5QCI) including an indication of at least one of a service type (latency critical GBR), the anticipated periodicity, payload size, and/or time offset information. In one embodiment, the method may then include, at 660, signaling, to a UE, configuration and activation of SPS resource allocation pattern with the service type, the desired periodicity and/or time offset information as received from the CN node. Subsequently, there may be a change of periodic traffic timing and, when such a change occurs, the method may include, at 670, receiving, from the CN, updated timing information with updated periodicity, updated payload size, and updated time offset information. In an embodiment, the method may then include, at 680, signaling updated configuration of SPS resource allocation to match the new timing information. In an embodiment, the signaling 680 may include sending the SPS resource allocation configuration via RRC signaling, while activation may be via MAC-CE signaling or PHY signaling (PDCCH), for example.

**[0079]** Therefore, certain example embodiments provide several technical improvements, enhancements, and/or advantages. Various example embodiments provide a method for reducing application latency for periodic data transmission in radio access networks. As a result, network throughput and UE throughput performance are improved. As such, example embodiments can improve performance, latency, and throughput of networks and network nodes including, for example, access points, base stations/eNBs/gNBs, and mobile devices or UEs. Accordingly, the use of certain example embodiments result in improved functioning of communications networks and their nodes.

**[0080]** 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.

**[0081]** 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 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.

**[0082]** 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 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 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.

**[0083]** 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 include a record medium, computer memory, read-only memory, photoelectrical and/or electrical carrier 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.

**[0084]** 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 implemented as a signal, a non-tangible means that can be carried by an electromagnetic signal downloaded from the Internet or other network.

**[0085]** According to an 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.

**[0086]** One having ordinary skill in the art will readily understand that example embodiments as discussed above may be practiced with steps in a different order, and/or with hardware elements in configurations which are different than those which are disclosed. Therefore, although some example embodiments have been described, 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 certain embodiments. In order to determine the metes and bounds of example embodiments, therefore, reference should be made to the appended claims.

WE CLAIM:

1. A method, comprising:

computing periodicity and time offset information of an application or service; and

signaling, by a core network, a service type, the periodicity, and the time-offset information to a new radio (NR) node.

2. The method according to claim 1, wherein the time-offset information comprises information about an absolute arrival time of a packet belonging to a periodic allocation.

3. The method according to claims 1 or 2, further comprising, when there is a change in periodic traffic timing, signaling updated timing information with updated periodicity, updated packet size, and updated time-offset information.

4. The method according to claims 1 or 2, further comprising periodically signaling updated timing information with updated periodicity, updated packet size, and updated time-offset information.

5. The method according to any one of claims 1-4, wherein the time-offset information comprises a SPSOffset_SFN field including a system frame number (SFN) where the value belongs and a SPSOffset_QTI field including an index related to a uniformly quantized time index in the system frame number (SFN) duration.

6. The method according to claim 5, further comprising computing the time-offset information as: $\delta = \text{SPSOffset\_SFN} + 2^{-L} \cdot \text{SPSOffset\_Offset}$.

7. The method according to any one of claims 1-6, wherein said application or service requires ultra-reliable low-latency communication (URLLC).

8. 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

compute periodicity and time offset information of an application or service; and

signal a service type, the periodicity, and the time-offset information to a new radio (NR) node.

9. The apparatus according to claim 8, wherein the time-offset information comprises information about an absolute arrival time of a packet belonging to a periodic allocation.

10. The apparatus according to claims 8 or 9, wherein, when there is a change in periodic traffic timing, 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 signal updated timing information with updated periodicity, updated packet size, and updated time-offset information.

11. The apparatus according to claims 8 or 9, 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 periodically signal updated timing information with updated periodicity, updated packet size, and updated time-offset information.

12. The apparatus according to any one of claims 8-11, wherein the time-

offset information comprises a SPSOffset_SFN field including a system frame number (SFN) where the value belongs and a SPSOffset_QTI field including an index related to a uniformly quantized time index in the system frame number (SFN) duration.

13. The apparatus according to claim 12, 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 compute the time-offset information as: $\delta = \text{SPSOffset\_SFN} + 2^{-L} \cdot \text{SPSOffset\_Offset}$.

14. The apparatus according to any one of claims 8-13, wherein said application or service requires ultra-reliable low-latency communication (URLLC).

15. An apparatus, comprising:

computing means for computing periodicity and time offset information of an application or service; and

signaling means for signaling a service type, the periodicity, and the time-offset information to a new radio (NR) node.

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

computing periodicity and time offset information of an application or service; and

signaling a service type, the periodicity, and the time-offset information to a new radio (NR) node.

17. A method, comprising:

receiving, from a core network, an indication of a service type, periodicity, and time-offset information of an application or service; and configuring, by a new radio (NR) node, a semi-persistent scheduling (SPS) resource allocation to be in coherence with the received service type, periodicity, and time-offset information.

18. 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, from a core network, an indication of a service type, periodicity, and time-offset information of an application or service; and

configure a semi-persistent scheduling (SPS) resource allocation to be in coherence with the received service type, periodicity, and time-offset information.

19. An apparatus, comprising:

receiving means for receiving, from a core network, an indication of a service type, periodicity, and time-offset information of an application or service; and

configuring means for configuring a semi-persistent scheduling (SPS) resource allocation to be in coherence with the received service type, periodicity, and time-offset information.

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

receiving, from a core network, an indication of a service type, periodicity, and time-offset information of an application or service;

configuring a semi-persistent scheduling (SPS) resource allocation to be in coherence with the received service type, periodicity, and time-offset information.

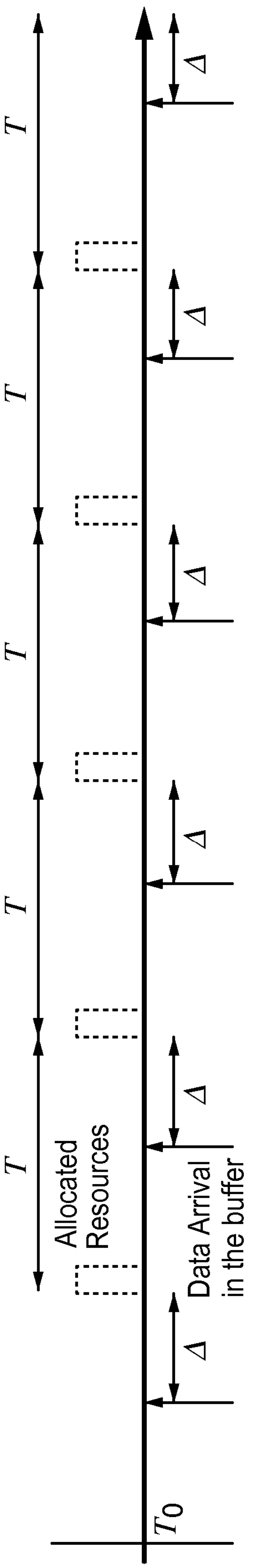


Fig. 1

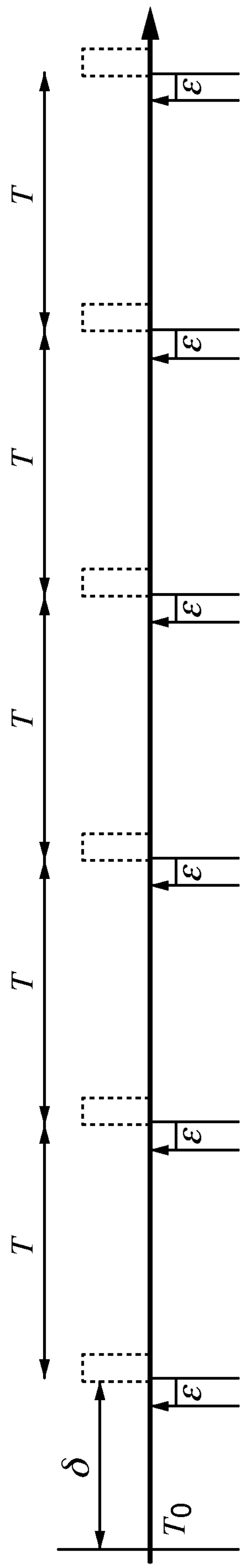


Fig. 2

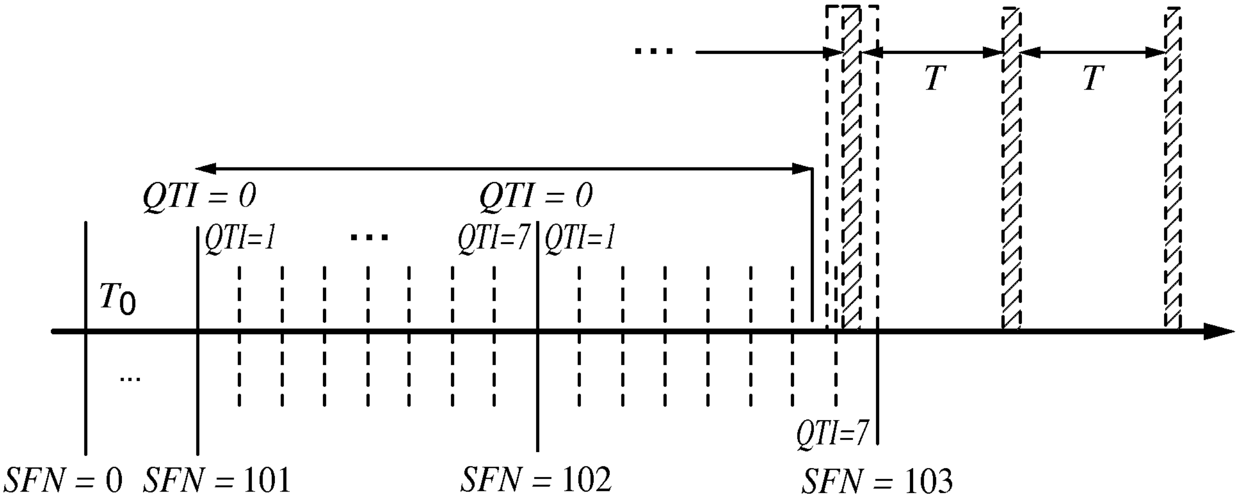
...
T
T
QTI = 0
QTI = 0
QTI=1
...
QTI=7
QTI=1
$T_0$
...
QTI=7
SFN = 0
SFN = 101
SFN = 102
SFN = 103

Fig. 3

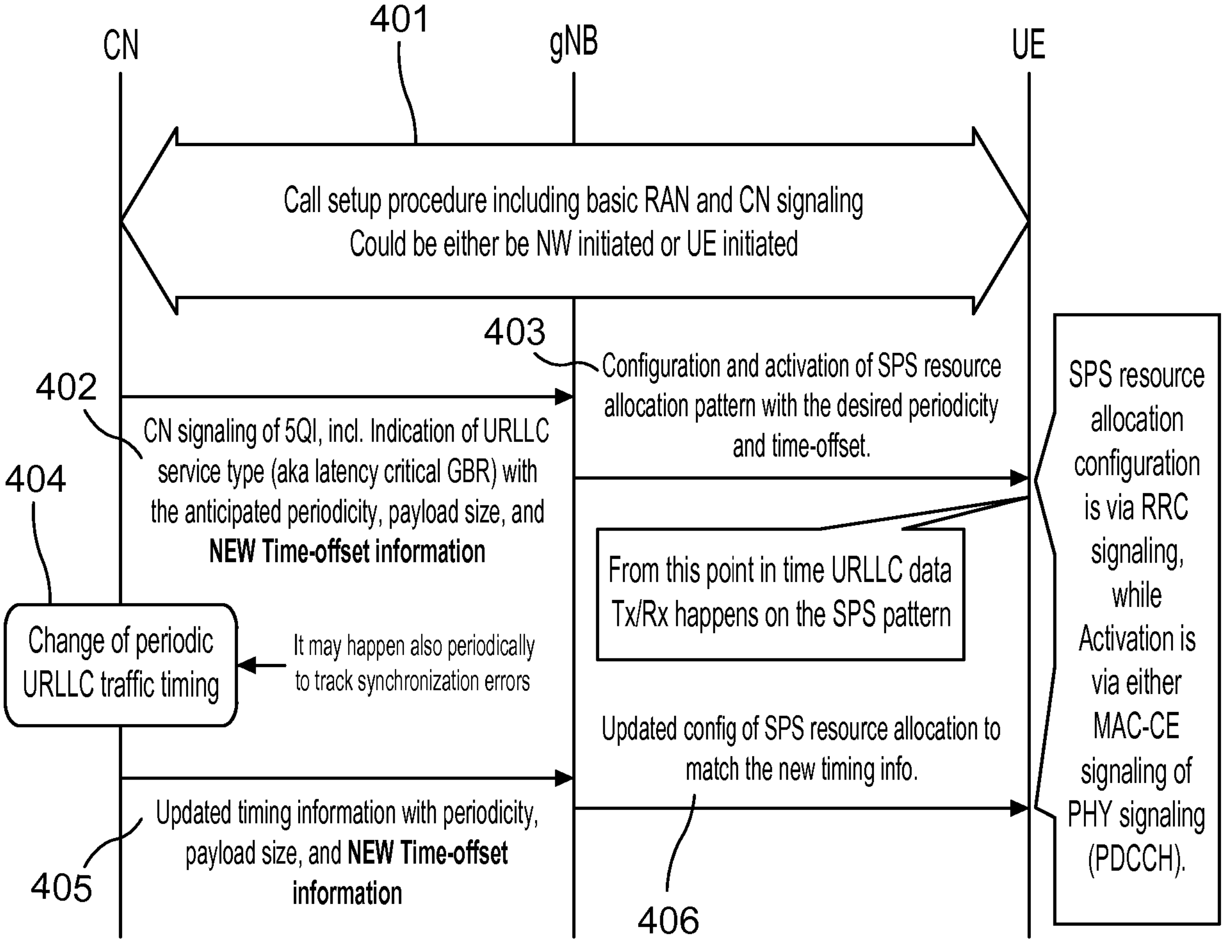
401
CN
gNB
UE
Call setup procedure including basic RAN and CN signaling
Could be either be NW initiated or UE initiated
403
Configuration and activation of SPS resource allocation pattern with the desired periodicity and time-offset.
402
CN signaling of 5QI, incl. Indication of URLLC service type (aka latency critical GBR) with the anticipated periodicity, payload size, and **NEW Time-offset information**
404
From this point in time URLLC data Tx/Rx happens on the SPS pattern
SPS resource allocation configuration is via RRC signaling, while Activation is via either MAC-CE signaling of PHY signaling (PDCCH).
Change of periodic URLLC traffic timing
It may happen also periodically to track synchronization errors
Updated config of SPS resource allocation to match the new timing info.
Updated timing information with periodicity, payload size, and **NEW Time-offset information**
405
406

Fig. 4

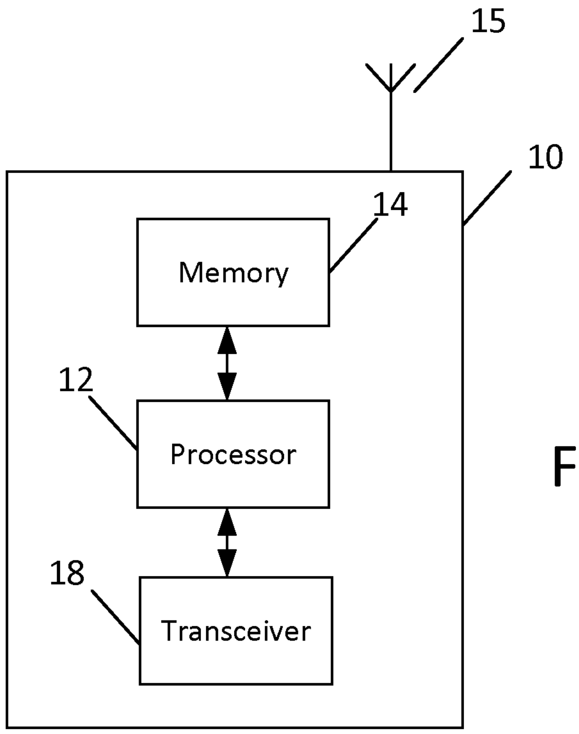
15
10
14
Memory
12
Processor
18
Transceiver

Fig. 5a

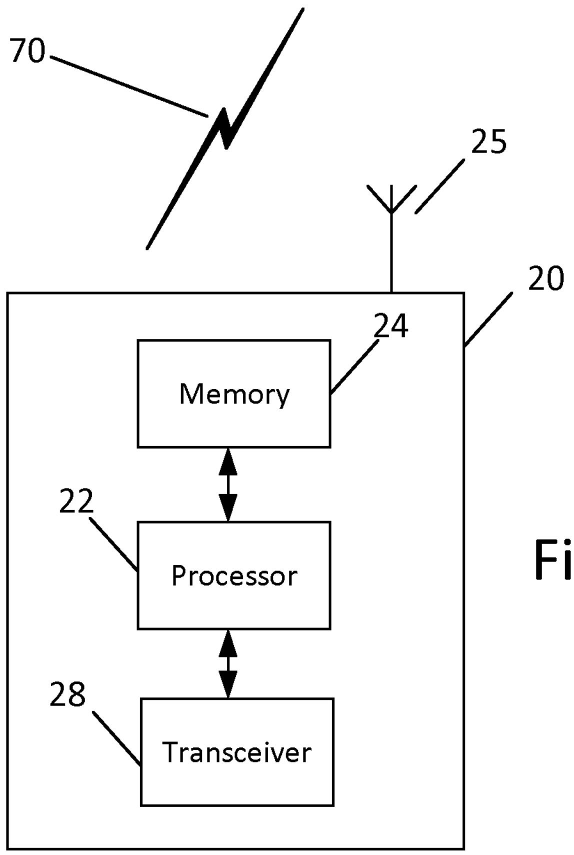
70
25
20
24
Memory
22
Processor
28
Transceiver

Fig. 5b

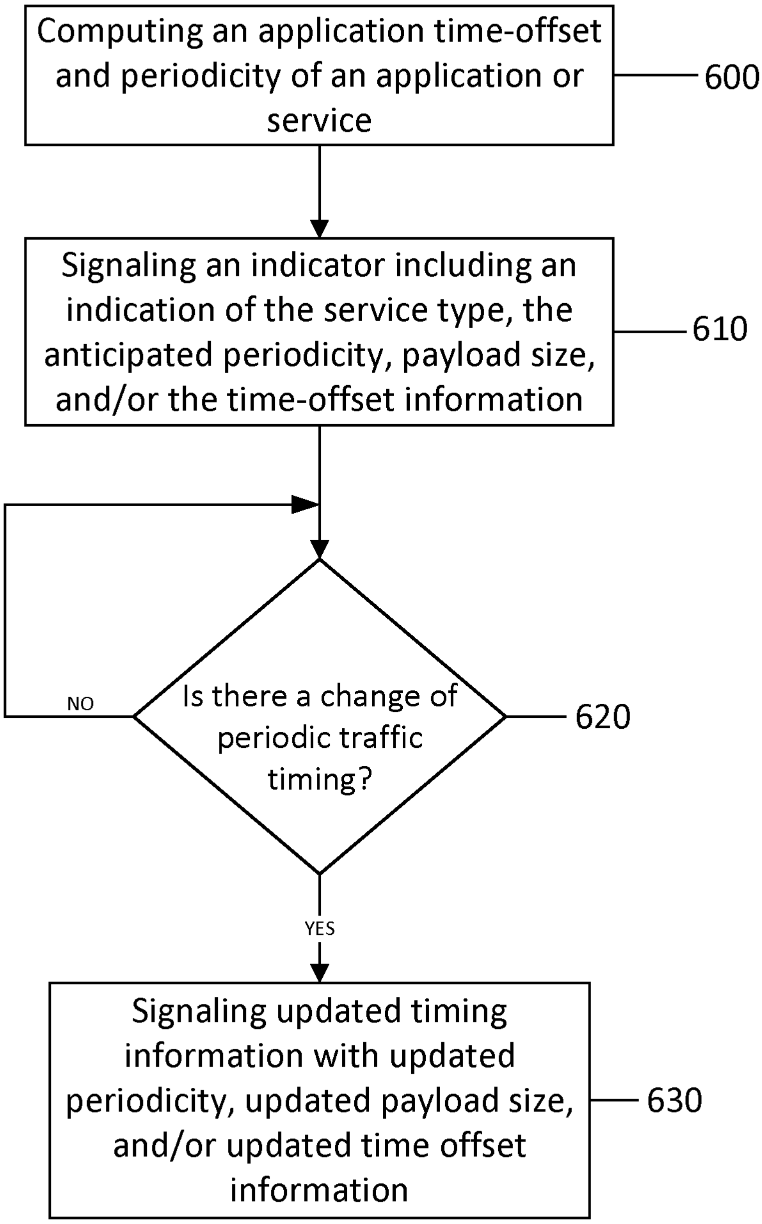
Computing an application time-offset and periodicity of an application or service
600
Signaling an indicator including an indication of the service type, the anticipated periodicity, payload size, and/or the time-offset information
610
Is there a change of periodic traffic timing?
NO
620
YES
Signaling updated timing information with updated periodicity, updated payload size, and/or updated time offset information
630

Fig. 6a

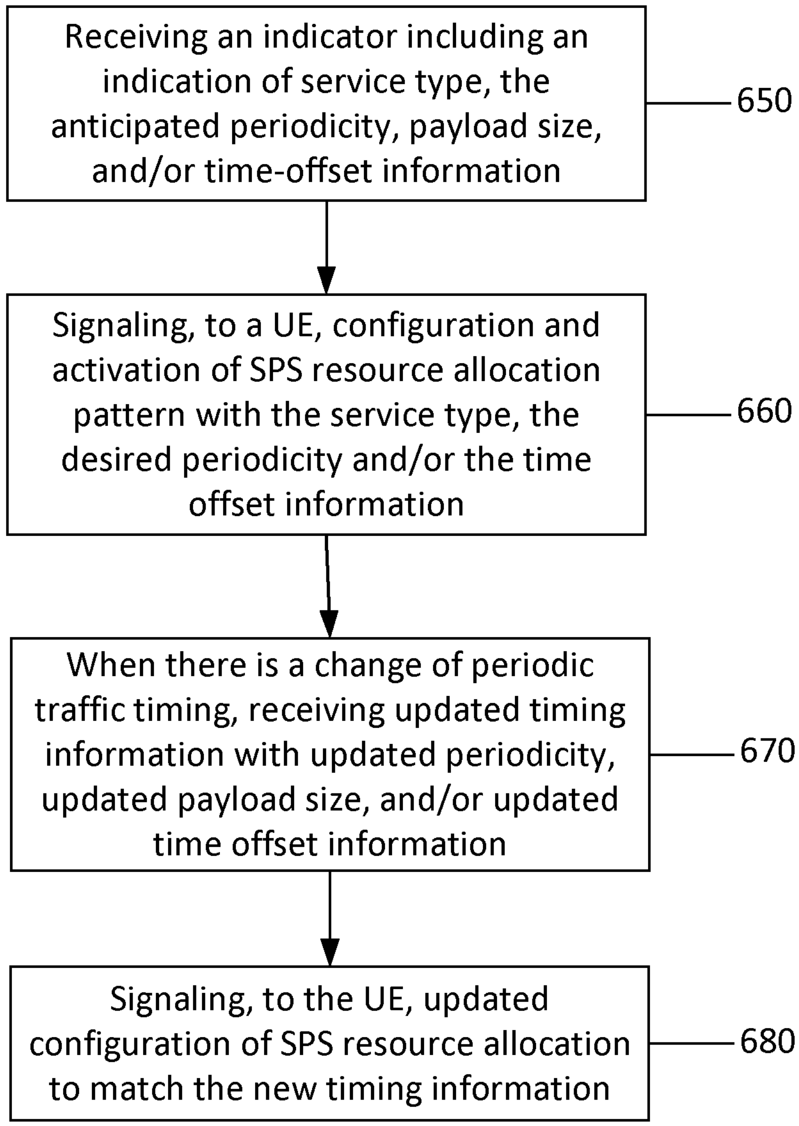
Receiving an indicator including an indication of service type, the anticipated periodicity, payload size, and/or time-offset information
650
Signaling, to a UE, configuration and activation of SPS resource allocation pattern with the service type, the desired periodicity and/or the time offset information
660
When there is a change of periodic traffic timing, receiving updated timing information with updated periodicity, updated payload size, and/or updated time offset information
670
Signaling, to the UE, updated configuration of SPS resource allocation to match the new timing information
680

Fig. 6b

# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/052683

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W72/04
ADD.

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | WO 2017/172479 A1 (INTERDIGITAL PATENT HOLDINGS INC [US]) 5 October 2017 (2017-10-05) paragraph [0073] - paragraph [0099] ----- | 1-20 |

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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| 8 October 2018 | 16/10/2018 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Martos Riaño, Demian |

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# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/052683

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | NOKIA ET AL: "Unified SPS and Grant-free operation", 3GPP DRAFT; R2-1708767 UNIFIED SPS AND GRANT-FREE OPERATION, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG2, no. Berlin, Germany; 20170621 - 20170625 20 August 2017 (2017-08-20), XP051318572, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN2/Docs/ [retrieved on 2017-08-20] the whole document ----- | 1-20 |

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# INTERNATIONAL SEARCH REPORT

**Information on patent family members**

International application No
PCT/EP2018/052683

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
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| WO 2017172479 A1 | 05-10-2017 | NONE | |