ENHANCED PAGING

RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 63/550,514, filed February 6, 2024, the disclosure of which is hereby incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates to a cellular communications system and, more specifically, paging in a cellular communications system.

BACKGROUND

[0003] For a cell in 3rd Generation Partnership Project (3GPP) New Radio (NR), typically, a Synchronization Signal Block (SSB) is transmitted periodically, and it may be used to aid a User Equipment (UE)'s initial cell search, acquire frame/slot timing, initial time/frequency synchronization, measurements, and as a Quasi Co-Located (QCL) reference for channels/signals, etc. With beamforming, SSBs must be transmitted in multiple beams, and this can lead to further increased network energy consumption.

[0004] When the network (NW) is in idle/very-low load scenario, main contributors to network energy consumption may include SSB transmissions, System Information (SI) transmissions, monitoring for uplink (e.g. listening to Random Access Channel (RACH) in RACH occasions), and transmission of paging messages. In Idle/inactive mode, UEs monitor paging in periodic occasions indicated via higher layers and based on UE Identities (IDs). The UE monitors one Paging Occasion (PO) per Discontinuous Reception (DRX) cycle. A PO is a set of Physical Downlink Control Channel (PDCCH) monitoring occasions and can consist of multiple time slots (e.g. subframe or Orthogonal Frequency Division Multiplexing (OFDM) symbol) where paging Downlink Control Information (DCI) can be sent (see, e.g., 3GPP Technical Specification (TS) 38.213 V18.1.0). One Paging Frame (PF) is one Radio Frame and may contain one or multiple PO(s) or starting point of a PO. In multi-beam operations, the UE can assume that the same paging message is repeated in all transmitted beams and thus the selection of the beam(s) for the reception of the paging message is up to UE implementation. The paging message is same for both Radio Access Network (RAN) initiated paging and Core Network (CN) initiated paging. The UE initiates the Radio Resource Control (RRC) Connection Resume procedure upon receiving RAN initiated paging. If the UE receives a CN initiated paging in RRC_INACTIVE state, the UE moves to RRC_IDLE and informs the Non-Access

Stratum (NAS).

[0005] The PF and PO for paging are determined by the following formulae:

- System Frame Number (SFN) for the PF is determined by:

  (SFN + PF_offset) mod T = (T div N)*(UE_ID mod N)

- Index (i_s), indicating the index of the PO is determined by:

  i_s = floor (UE_ID/N) mod Ns

The following parameters are used for the calculation of PF and i_s above:

- T: DRX cycle of the UE (T is determined by the shortest of the UE specific DRX value, if configured by RRC or upper layers, and a default DRX value broadcast in system information. If UE specific DRX is not configured by RRC or by upper layers, the default value is applied).
- N: number of total paging frames in T
- Ns: number of paging occasions for a PF
- PF_offset: offset used for PF determination
- UE_ID: 5G-S-TMSI mod 1024

Parameters *Ns*, *firstPDCCH-MonitoringOccasionOfPO*, *nAndPagingFrameOffset*, and the length of default DRX Cycle are signaled in System Information Block 1 (SIB1). The values of N and PF_offset are derived from the parameter *nAndPagingFrameOffset* as defined in 3GPP TS 38.331 V18.0.0. If the UE has no 5th Generation System Architecture Evolution (SAE) Temporary Mobile Subscriber Identity (5G-S-TMSI), for instance when the UE has not yet registered onto the network, the UE shall use as default identity UE_ID = 0 in the PF and i_s formulas above. 5G-S-TMSI is a 48 bit long bit string as defined in 3GPP TS 23.501 V18.4.0. 5G-S-TMSI shall in the formulae above be interpreted as a binary number where the left most bit represents the most significant bit.

[0006] The paging configuration is carried in higher layer signaling and includes the following.

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defaultPagingCycle        PagingCycle,
nAndPagingFrameOffset     CHOICE {
  oneT              NULL,
  halfT             INTEGER (0..1),
  quarterT          INTEGER (0..3),
  oneEighthT        INTEGER (0..7),
  oneSixteenthT     INTEGER (0..15)
},
ns                ENUMERATED {four, two, one},
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[0007] The PDCCH monitoring occasions for paging are determined according to *pagingSearchSpace* as specified in 3GPP TS 38.213 and *firstPDCCH-MonitoringOccasionOfPO* if configured as specified in 3GPP TS 38.331. Otherwise, when *SearchSpaceId* = 0 is configured for *pagingSearchSpace*, the PDCCH monitoring occasions for paging are same as for Remaining Minimum System Information (RMSI) as defined in clause 13 in 3GPP TS 38.213.

[0008] When *SearchSpaceId* = 0 is configured for *pagingSearchSpace*, Ns is either 1 or 2. For Ns = 1, there is only one PO which starts from the first PDCCH monitoring occasion for paging in the PF. For Ns = 2, PO is either in the first half frame (i_s = 0) or the second half frame (i_s = 1) of the PF.

[0009] When *SearchSpaceId* other than 0 is configured for *pagingSearchSpace,* the UE monitors the $(i_s + 1)^{th}$ PO. A PO is a set of 'S' consecutive PDCCH monitoring occasions where 'S' is the number of actual transmitted SSBs determined according to *ssb-PositionsInBurst* in *SIB1*. The K^{th} PDCCH monitoring occasion for paging in the PO corresponds to the K^{th} transmitted SSB. The PDCCH monitoring occasions for paging which do not overlap with UL symbols are sequentially numbered from zero starting from the first PDCCH monitoring occasion in the PF. When *firstPDCCH-MonitoringOccasionOfPO* is present, the starting PDCCH monitoring occasion number of $(i_s + 1)^{th}$ PO is the $(i_s + 1)^{th}$ value of the *firstPDCCH-MonitoringOccasionOfPO* parameter; otherwise, it is equal to i_s * S.

[0010] A PO associated with a PF may start in the PF or after the PF.

[0011] When *SearchSpaceId* other than 0 is configured for *paging-SearchSpace*, the PDCCH monitoring occasions for a PO can span multiple radio frames and multiple periods of the paging search space.

[0012] Transmitting paging messages to different UEs in different slots/subframes/SFNs consumes energy at the gNodeB (gNB) (e.g. to wake up from a sleep state just to transmit a paging message, etc.).

SUMMARY

[0013] Systems and methods related to enhanced paging in a cellular communications system are disclosed. In one embodiment, a method performed by a User Equipment (UE) for paging monitoring comprises receiving an enhanced paging configuration from a network node, the enhanced paging configuration comprising a parameter that defines a number of paging occasions within a paging frame as one of a set of predefined values comprising at least one value that is greater than 4. The method further comprises monitoring for a paging message in accordance with the enhanced paging configuration. In this manner, paging configuration is enhanced to facilitate network energy savings and/or reduced impact on UE power savings.

[0014] In one embodiment, the set of predefined values from which the number of paging occasions within a paging frame is defined comprises the value of 8.

[0015] In one embodiment, the method further comprises receiving a first paging configuration. In one embodiment, the first paging configuration is a legacy paging configuration.

[0016] In one embodiment, the enhanced paging configuration is based on the first paging configuration. In one embodiment, one or more parameters of the first paging configuration may further define the enhanced paging configuration such that the paging frames and/or paging occasions defined by the first paging configuration do not overlap with the paging frames and/or paging occasions defined by the enhanced paging configuration. In one embodiment, monitoring for paging according to the enhanced paging configuration comprises monitoring for paging according to the enhanced paging configuration using a paging frame offset parameter given by the first paging configuration as an offset in a determination of paging frame.

[0017] In one embodiment, the enhanced paging configuration is independent of the first paging configuration.

[0018] In one embodiment, the enhanced paging configuration comprises one or more parameters that over-ride one or more corresponding parameters in the first paging configuration.

[0019] In one embodiment, the enhanced paging configuration comprises information that indicates a new value for at least one parameter comprised in the first paging configuration.

[0020] In one embodiment, the enhanced paging configuration comprises one or more parameters that are not included in the first paging configuration. In one embodiment, the one or more parameters that are not included in the first paging configuration comprises a parameter that indicates a number of paging frames in a paging frame group.

[0021] In one embodiment, one or more characteristics of the enhanced paging configuration are different than those of the first paging configuration, the one or more characteristics comprising any one or more of the following: one or more scheduling characteristics; Control Resource Set (CORESET) and/or search space; one or more encoding characteristics.

[0022] In one embodiment, the UE monitors for a paging message in paging frames and paging occasions according to the enhanced paging configuration and does not monitor for a paging message in paging frames and paging occasions according to the first paging configuration.

[0023] In one embodiment, the UE determines which of the first and enhanced paging configurations to use. In one embodiment, the UE determines which of the first and enhanced paging configuration to use based on an indication received from a network node. In another embodiment, the UE determines which of the first and enhanced paging configuration to use

based on a defined prioritization scheme.

[0024] In one embodiment, receiving the enhanced paging configuration comprises receiving the enhanced paging configuration via dedicated signaling or via broadcast system information.

[0025] In one embodiment, the enhanced paging configuration further comprises information that indicates a number of paging frames in a paging frame group. In one embodiment, the method further comprises determining one or more paging frames for monitoring for a paging message based on the indicated number of paging frames in a paging frame group. In one embodiment, determining the one or more paging frames for monitoring for a paging message is further based on one or more additional parameters signaled by the network node. In one embodiment, the one or more paging frames are determined in accordance with:

$$(SFN + PF_offset) \bmod T =$$
$$N_G * (T \operatorname{div} (N/N_G)) * \operatorname{floor}((UE_ID \bmod N)/N_G) + ((UE_ID \bmod N) \bmod N_G)$$

wherein:

- SFN is a system frame number,
- PF_offset is an offset derived from a parameter indicated either in the enhanced paging configuration or another paging configuration on which the enhanced paging configuration is based,
- N_G is a number of paging frames in a paging frame group,
- T is a DRX cycle indicated in broadcast system information,
- N is a number of total paging frames in T and is derived from a parameter indicated in either in the enhanced paging configuration or another paging configuration on which the enhanced paging configuration is based, and
- UE_ID is an identity of the UE.

[0026] In another embodiment, the one or more paging frames are determined in accordance with:

$$(SFN + PF_offset) \bmod T =$$
$$N_G * (T \operatorname{div} (N/N_G)) * \operatorname{floor}((UE_ID \bmod N)/N_G) + gap * ((UE_ID \bmod N) \bmod N_G)$$

wherein:

- SFN is a system frame number,
- PF_offset is an offset derived from a parameter indicated either in the enhanced paging configuration or another paging configuration on which the enhanced paging configuration is based,
- N_G is a number of paging frames in a paging frame group,
- T is a DRX cycle indicated in broadcast system information,
- N is a number of total paging frames in T and is derived from a parameter indicated

in either in the enhanced paging configuration or another paging configuration on which the enhanced paging configuration is based,

- UE_ID is an identity of the UE, and
- gap is a size of a gap between adjacent paging frames of a paging frame group.

[0027] In another embodiment, the one or more paging frames are determined in accordance with:

$$(SFN + PF_offset) \bmod T = N_G * (T \operatorname{div} (N/N_G)) * \operatorname{floor}((UE_ID \bmod N)/N_G) + F(((UE_ID \bmod N) \bmod N_G))$$

wherein:

- F(0) = 0, F(1) = 1, F(2)=3, F(3) = 4;
- SFN is a system frame number,
- PF_offset is an offset derived from a parameter indicated either in the enhanced paging configuration or another paging configuration on which the enhanced paging configuration is based,
- N_G is a number of paging frames in a paging frame group,
- T is a DRX cycle indicated in broadcast system information,
- N is a number of total paging frames in T and is derived from a parameter indicated in either in the enhanced paging configuration or another paging configuration on which the enhanced paging configuration is based, and
- UE_ID is an identity of the UE.

[0028] In another embodiment, the one or more paging frames are determined in accordance with a reference SFN determined by:

$$(Reference\text{-}SFN + PF_offset) \bmod T = (T \operatorname{div} N) * (UE_ID \bmod N), \text{ and}$$

an index (i_s) indicating an index of a paging occasion is determined by:

$$i_s = \operatorname{floor}(UE_ID/N) \bmod Ns,$$

where:

- T is a DRX cycle indicated in broadcast system information,
- N is a number of total paging frames in T and is derived from a parameter indicated in the first paging configuration,
- Ns is a number of paging occasions for a paging frame and is indicated in a first paging configuration,
- PF_offset is an offset derived from the parameter indicated in the first paging configuration, and
- UE_ID is an identity of the UE; and

determining the one or more PFs comprises determining the number of PFs based on the

reference SFN and a parameter, comprised in the enhanced paging configuration, that indicates the number of PFs within a paging frame group (PFG).

[0029] Corresponding embodiments of a UE are also disclosed. In one embodiment, a UE for paging monitoring is adapted to receive, from a network node, an enhanced paging configuration that configures the UE with a parameter that defines a number of paging occasions within a paging frame as one of a set of predefined values comprising at least one value that is greater than 4. The UE is further adapted to monitor for a paging message in accordance with the enhanced paging configuration.

[0030] In one embodiment, a UE for paging comprises a communication interface comprising a transmitter and a receiver, and processing circuitry associated with the communication interface. The processing circuitry is configured to cause the UE to receive, from a network node, an enhanced paging configuration that configures the UE with a parameter that defines a number of paging occasions within a paging frame as one of a set of predefined values comprising at least one value that is greater than 4. The processing circuitry is further configured to cause the UE to monitor for a paging message in accordance with the enhanced paging configuration.

[0031] Embodiments of a method performed by a network node for configuration of paging monitoring are also disclosed. In one embodiment, a method performed by a network node for configuration of paging monitoring comprises sending an enhanced paging configuration to a UE, the enhanced paging configuration comprises a parameter that defines a number of paging occasions within a paging frame as one of a set of predefined values comprising at least one value that is greater than 4.

[0032] Corresponding embodiments of a network node are also disclosed. In one embodiment, a network node for configuration of paging monitoring is adapted to send an enhanced paging configuration to a UE, the enhanced paging configuration comprises a parameter that defines a number of paging occasions within a paging frame as one of a set of predefined values comprising at least one value that is greater than 4.

[0033] In one embodiment, a network node for configuration of paging monitoring comprises processing circuitry configured to cause the network node to send an enhanced paging configuration to UE, the enhanced paging configuration comprises a parameter that defines a number of paging occasions within a paging frame as one of a set of predefined values comprising at least one value that is greater than 4.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] The accompanying drawing figures incorporated in and forming a part of this

specification illustrate several aspects of the disclosure, and together with the description serve to explain the principles of the disclosure.

[0035] Figure 1 illustrates an example embodiment of the present disclosure in which Paging Frames (PFs) within a Paging Frame Group (PFG) are in consecutive System Frame Numbers (SFNs);

[0036] Figure 2 illustrates an example embodiment of the present disclosure in which PFs within a PFG are in non-consecutive SFNs but still clustered together;

[0037] Figure 3 illustrates another example embodiment having two parts, namely, a top part that illustrates the paging frames in one DRX cycle would be distributed according to the usual paging configuration and a second part that illustrates the actual paging frames of the UE determined based on its reference paging frame and a parameter indicative of the number of PFs within a PFG;

[0038] Figure 4 illustrates the operation of a User Equipment (UE) and a network node in accordance with at least some embodiments of the present disclosure;

[0039] Figure 5 shows an example of a communication system in accordance with some embodiments of the present disclosure;

[0040] Figure 6 shows a UE in accordance with some embodiments of the present disclosure;

[0041] Figure 7 shows a network node in accordance with some embodiments of the present disclosure;

[0042] Figure 8 is a block diagram of a host, which may be an embodiment of the host of Figure 5, in accordance with various aspects of the present disclosure described herein;

[0043] Figure 9 is a block diagram illustrating a virtualization environment in which functions implemented by some embodiments of the present disclosure may be virtualized; and

[0044] Figure 10 shows a communication diagram of a host communicating via a network node with a UE over a partially wireless connection in accordance with some embodiments of the present disclosure.

DETAILED DESCRIPTION

[0045] The embodiments set forth below represent information to enable those skilled in the art to practice the embodiments and illustrate the best mode of practicing the embodiments. Upon reading the following description in light of the accompanying drawing figures, those skilled in the art will understand the concepts of the disclosure and will recognize applications of these concepts not particularly addressed herein. It should be understood that these concepts and applications fall within the scope of the disclosure.

[0046] Some of the embodiments contemplated herein will now be described more fully with

reference to the accompanying drawings. Embodiments are provided by way of example to convey the scope of the subject matter to those skilled in the art.

[0047] There currently exist certain challenge(s). Paging frames in 3rd Generation Partnership Project (3GPP) Release (Rel-) 18 (and earlier releases) are uniformly distributed within a paging cycle, which can lead to increased gNodeB (gNB) wake-ups just to transmit paging messages, consuming energy on the network side. Being able to confine paging occasions in time can be beneficial, but detailed solutions on how to enable such functionality via signaling are missing.

[0048] Certain aspects of the disclosure and their embodiments may provide solutions to these or other challenges. Embodiments of systems and methods are disclosed that introduce a paging frame group and/or associated signaling to facilitate paging messages that can be confined in time. One or more possible expressions for Paging Frame (PF) determination to facilitate confined paging are also disclosed, including flexible placement/allocation of PFs within the Discontinuous (DRX) cycle, and optionally modified Paging Occasion (PO) placement within the PFs, to facilitate network energy savings/scheduling flexibility. User Equipment (UE) behavior in case of two paging configurations (legacy and enhanced paging) in the cell, including how/when UE monitors POs corresponding to the one or more of the two paging configurations is also described.

[0049] The second paging configuration information may be provided via new or modified dedicated Radio Resource Control (RRC) signaling, or via new or modified System Information Block (SIB) contents.

[0050] Certain embodiments may provide one or more of the following technical advantage(s). Embodiments of the present disclosure may provide a simple way to modify the PF and PO determination without unduly increasing the UE/gNB implementation complexity while facilitating network energy savings and/or reduced impact on UE power savings. Embodiments of the present disclosure may introduce multiple paging configurations that can be configured/utilized in different ways to enable different use cases/energy performance.

[0051] Now, a more detailed description of exemplary embodiments of the present disclosure will be provided.

[0052] Higher layer signaling is used to indicate a paging configuration. Below is an example illustrating how paging frames are determined for legacy UEs based on paging configuration.

[0053] **Example 1 - Paging frame configuration with defaultPagingCycle =rf128, quarterT with value 0, Ns=1:** Given the default paging cycle duration of 128 radio frames and with a nAndPagingFrameOffset given by quarterT value = 0, there would be 128/ 4 = 32 paging

frames, and these paging frames would occur in SFN0, SFN4, SFN8,…. Thus, in a paging cycle of 1.28 seconds (s), there can be 32 paging frames, occurring with a periodicity of 40 milliseconds (ms). The exact PF used to page a UE is determined based on UE ID (System Architecture Evolution (SAE) Temporary Mobile Subscriber Identity (S-TMSI)), etc.

[0054] The parameter Ns is used indicate the number of POs in a paging frame. Thus, when Ns =1, there are total 32 x 1 = 32 POs configured in the cell.

[0055] The UE determines the PF and the PO associated with the UE ID based on the indicated signaling. When the UE is in Idle/Inactive, the UE monitors for paging in the monitoring occasion(s) associated with the determined PO (e.g. monitors for Paging Radio Network Temporary Identity (P-RNTI) in the paging search space, and corresponding Physical Downlink Shared Channel (PDSCH), if any) and looks for its UE ID/Temporary Mobile Subscriber Identity (TMSI). If the UE finds its UE ID/TMSI, the UE may initiate a Random Access Channel (RACH) procedure by transmitting a Physical Random Access Channel (PRACH) and monitoring for the response (e.g. to initiate an RRC connection). In another example, the UE may monitor for P-RNTI and receive a short message that indicates a System Information (SI) change, etc., and subsequently, may acquire the further system information.

[0056] **Example 2:** If Ns=2, there can be total of 32 x2 = 64 POs configured in the cell.

[0057] Embodiments of the solution(s) disclosed herein related to additional PFs/POs for UEs based on additional/new paging configuration/parameters will now be described. In this regard, in higher layer signaling (e.g. SI, RRC, etc.), for a cell, a first paging configuration can be configured (e.g. a legacy paging configuration), and a second paging configuration (an enhanced paging configuration) can be configured. A UE may indicate a capability to support paging monitoring according to a second paging configuration (e.g. an enhanced paging configuration).

[0058] The first paging configuration may be a legacy paging configuration.

[0059] The second paging configuration may be determined based on the first paging configuration with additional configuration of one or more new parameter(s) indicated via higher layer signaling (e.g. number of paging frames in a paging frame group, new PF locations, and an additional Ns parameter). An example is shown below.

[0060] The second paging configuration may be determined based on the first paging configuration with additional one or more extension parameter(s) that are used to over-ride corresponding parameter(s) from the first paging configuration.

[0061] The second paging configuration may alternatively be a standalone configuration, separate and independent of the first paging configuration, indicated via higher layer signaling.

[0062] In one embodiment, one or more parameters of the first paging configuration may further define the second paging configuration such that the paging frames and/or occasions defined by the first paging configuration do not overlap with the paging frames and/or occasions defined by the second paging configuration (or overlap only a certain amount). In this way, it can be ensured that there is sufficient paging capacity for (legacy) UEs that only rely on the first (legacy) paging configuration. In one example, a UE that is configured to monitor for paging according to the second paging configuration may use/apply the parameter Ns (number of paging occasions for a paging frame) given by the first paging configuration as an offset in the determination of paging occasion index i_s. Thus, a UE that is configured to monitor for paging according to the second paging configuration would not be mapped to a paging occasion to which any UE that is configured to monitor for paging according to the first paging configuration is mapped to. In another example, a UE that is configured to monitor for paging according to the second paging configuration may use/apply the parameter PF_offset (offset used for paging frame determination) given by the first paging configuration as an offset in the determination of paging frame.

[0063] In one embodiment, the type of paging configuration, i.e., the first (legacy) paging configuration or the second paging configuration etc., is indicated in the "paging information container" so that the gNB can page the UE accordingly when the paging request is received from the core network. Such indication can simply be a bit that indicates that the UE supports the "second indication". It may also be an integer that indicates the "number" of the paging configuration supported in the network assuming that there are multiple paging configurations in addition to the legacy configuration. Yet in another option, a bitmap is used to indicate the paging configurations that the UE supports, such indicates makes it possible for the UE to indicate supporting/monitoring for multiple paging configurations at once. Yet in another dependent embodiment, the indication may be captured in an enumerated parameter that refers to the corresponding paging configuration, or a string that contains the paging configuration(s).

[0064] The first and second paging configuration may have some identical parameters such as default paging cycle, Ns, etc.

[0065] The second paging configuration may be distinct from the first paging configuration.

[0066] When second paging configuration is indicated for a cell (e.g. in SI, RRC, etc.), UE may monitor PF/PO according to the second paging configuration only. In this example, the UE may monitor paging in one paging occasion in a DRX cycle.

[0067] When second paging configuration is indicated for a cell (e.g. in SI, RRC, etc.), UE may monitor PF/PO according to the first and second paging configurations. In this example, the UE may monitor paging in one or more paging occasions in a DRX cycle.

[0068] In an example, the first paging configuration can yield a first PO in a first PF and the second paging configuration can yield a second PO in a second PF. The UE may monitor both the first and second POs in a DRX cycle. The UE may determine the PO/PF to monitor, e.g. whether to monitor according to the first, second, or both configurations, based on a gNB indication. The indication from gNB may be in form of L1/L2 signaling. For example, the information can be embedded in a DCI sent in a common search space such as DCI scrambled by Paging Early Indication (PEI) Radio Network Temporary Identity (PEI-RNTI), SI-RNTI, P-RNTI, or another RNTI configured by higher layers. In one example, it can also be a Low Power Wake-Up Signal (LP-WUS) based on OFDM and/or On-Off Keying (OOK) signaling.

[0069] In certain embodiments, the PEI or LP-WUS configurations may be separate for the first and second paging configurations.

[0070] In certain embodiments, the PEI or LP-WUS configurations may be identical for the first and second paging configurations.

[0071] In certain embodiments, the legacy PEI is used for invoking both legacy UEs and the new UEs capable of receiving the second configured POs. For example, these new UEs assigned to the second configured POs may be assigned to other paging (sub)-groups compared to legacy UEs.

[0072] In general, for the embodiments of the present disclosure, it is also possible that multiple paging configurations are provided via system information broadcast or dedicated signaling. These paging configurations would then be in addition to the legacy, i.e., it may be labeled as primary, paging configuration. In that case, it may also be possible that the network provides information regarding the fallback configuration or paging configuration prioritization, e.g., which paging configuration(s) to be used if the UE is configured with a paging configuration(s) that is/are not enabled/supported in the serving cell. The paging configurations can be provided with respect to the legacy, i.e., primary, paging configuration. "With respect to" in this context refers to "delta" configuration, i.e., only provide the configuration for parameter(s) that have a different value with respect to the value(s) provided in the legacy paging configuration.

[0073] In one embodiment, a UE or a group of UEs, e.g., Reduced Capability (RedCap) UEs, are configured with a dedicated paging configuration(s). This configuration or these configurations can be prioritized over the legacy paging configuration if it is/they are enabled in the serving cell. If multiple paging configurations are enabled in the cell, the UE applies the one with the highest priority. For example, the RedCap devices (or a subgroup thereof) may be configured such that they are assigned to other or a subset of POs than that of enhanced Mobile Broadband (eMBB) devices.

[0074] In certain embodiments, the reference for PEI determination (reference for slot offset, etc.) may be explicitly indicated by higher layer signaling. The reference can be the first PF based on the first paging configuration for the UE. In certain embodiments, the UE may monitor the PO according to the second paging configuration based on the PEI determined from the first paging configuration.

[0075] In certain embodiments, the second configured paging provision characteristics can be different compared to the first configured paging. Examples of characteristics herein is one or more of:

- Scheduling characteristics. For example, the second configured paging may be configured with another PDSCH-TimeDomainResourceAllocation configuration with e.g. K0 > 0; meaning that the second paging PDSCH is provided in a cross-slot manner.
- Coreset and/or search space. For example, the second configured paging may be associated with one or more separate search spaces. As such, the NW may for example be able to provide the DCIs in other symbols than that of the first configured POs.
- Encoding characteristics. For example, another Transport Block (TB) Scaling value may be used for PDSCH encoding. Typically, the TB scaling information is provided to the UE as part of DCI. However, this information may in one embodiment be provided to the UE already upon configuration so that the UE already before receiving the DCI knows that TB Scaling is used.

[0076] In one embodiment, there may be different search spaces and different scheduling characteristics configured for the different second configured POs. As such, the DCIs of the individual POs can for example be provided back-to-back in multiple symbols and the associated PDSCHs (upon paging) can be provided in later symbols according to the associated PDSCH-TimeDomainResourceAllocation for different POs. Based on such scheme, when there is no paging message but only DCIs notifying about SI update or Public Warning System notification the DCIs can be provided in a condensed timeline.

[0077] Furthermore, the DCI of the second configured paging may be encoded with another RNTI than the DCI of the first configured paging. Furthermore, this new DCI may then contain other parameters than that of the first configured paging DCI. For example, paging subgrouping info could be provided.

[0078] For example, based on the embodiments above, including different scheduling/encoding characteristics and other DCI contents such as subgrouping info, the NW and the UE may enjoy similar savings as with legacy PEI.

[0079] In one embodiment, the new DCI for the second configured paging can include indications related to additional/auxiliary SSBs (additional to regular SSBs used for camping on

the cell) being provided at certain point after the DCI. For example, there may be a gap between the DCI and the paging PDSCH during which auxiliary SSBs are provided. Based on such indications, UEs (especially UEs in non-optimal coverage) may use the auxiliary SSB for extra fine-tuning before receiving the PDSCH.

[0080] Similarly, the said new DCI may further include indication for additional PRACH resources to be used for paging response.

[0081] In some embodiments, one or more parameters like *Ns*, *firstPDCCH-MonitoringOccasionOfPO*, *nAndPagingFrameOffset*, and the length of default DRX Cycle may be different between the first and second paging configurations.

[0082] Embodiments related to provision of the second paging configuration via SI broadcast are also disclosed. In this regard, in the above embodiments, the first and second paging configurations are provided to UEs via dedicated RRC signaling and the second paging configuration is available to compatible UEs after they have first connected to the NW but only while remaining camping in the same cell or paging area. In an alternative embodiment, relevant configuration information may be provided via SI broadcast, e.g. SIB1, so UEs moving around in the NW and camping on different cells and/or in different paging areas can continue to utilize the more efficient second paging configuration, although the specific second configuration parameters may differ in cells across the NW. Note that the NW and the UE are both aware of which POs (first and/or second) the UE is listening to based on earlier provided UE capability. Such UE capability is either maintained in UE context in the gNB during RRC Inactive state or is obtained from core NW in case of RRC Idle. However, in case the UE enters a cell where only legacy type of POs are configured/supported, the UE listens to the legacy POs.

[0083] In legacy cells, SIB1 contains the default pcch-config information. In one embodiment, SIB1 may additionally contain a secondary pcch-config field that provides the default second paging configuration info. The secondary pcch-config may contain additional parameters compared to the default pcch-config, contain same parameters with different values, or contain delta information in relation to the first configuration. Alternatively, the secondary pcch-config info, or equivalent, may be provided in another SIBn, n>1.

[0084] In one embodiment, UEs that, before transitioning to idle/inactive, have been configured to use the second paging configuration, may use the secondary pcch-config to obtain the secondary paging configuration when camping on a cell, or in a paging area, other than where they last were connected.

[0085] In another embodiment, the UE may receive DCI signaling in the camping cell to determine the paging configuration to be used, as described above. If the second paging configuration is indicated, the UE may use parameters provided in the secondary pcch-config for

paging monitoring.

[0086] Embodiments related to determination of PFs for UEs based on the additional/new paging configuration/parameters are also disclosed. In this regard, in certain embodiments, higher layers configure one or more of defaultPagingCycle, PagingCycle, nAndPagingFrameOffset, and Ns, and also configures an additional parameter that is indicative of the number of paging frames within a paging frame group.

[0087] An example formula with the number of paging frames in a paging frame group, N_G, used to determine the Paging frame location for the UE is given below.

$$(SFN + PF_offset) \bmod T =$$

$$N_G * (T \text{ div } (N/ N_G)) * \text{floor}((UE_ID \bmod N)/ N_G) + ((UE_ID \bmod N) \bmod N_G)$$

[0088] In an example, the PFs within the paging frame group may be in consecutive SFNs. An example is shown in Figure 1.

[0089] In another example, the gNB may prefer to still allow some gaps between the consecutive PFs within a paging frame group. In such cases, the gNB may configure one or more parameters to indicate the gap between consecutive PFs within a PFG, or a relative gap between the first PF of the PFG and the other PFs of the PFG. For example, the gNB may configure gap = 2. In this case the formula may be as follows.

$$(SFN + PF_offset) \bmod T =$$

$$N_G * (T \text{ div } (N/ N_G)) * \text{floor}((UE_ID \bmod N)/ N_G) + gap * ((UE_ID \bmod N) \bmod N_G)$$

[0090] In an example, the PFs within the paging frame group may be in non-consecutive SFNs (but still clustered together). An example is shown in Figure 2.

[0091] In yet another example, the gNB may explicitly configure the gap relative to the first PF of the PFG, as {0, 1, 3, 4}. In this case the formula may be as follows.

$$(SFN + PF_offset) \bmod T =$$

$$N_G * (T \text{ div } (N/ N_G)) * \text{floor}((UE_ID \bmod N)/ N_G) + F(((UE_ID \bmod N) \bmod N_G))$$

wherein $F(0) = 0$, $F(1) = 1$, $F(2)=3$, $F(3) = 4$.

[0092] The UE may then determine the SFN for the PF based on at least one or more of T, N, PF_Offset and the parameter indicative of the number of PFs within a paging frame group.

[0093] The Ns value can be used along with the PF determination to identify the PO location within the PF.

[0094] Another way of determining the UE's paging frame is described below. In this case, the UE may determine a first reference SFN for the PF, and based on a parameter indicative of a number of paging frames within a paging frame group, determine the actual SFN for the PF.

[0095] In an example, the SFN of the UE's Paging frame is determined as follows. The UE based on the configuration first determines a reference SFN which is given by the legacy

formula.

[0096] Reference-SFN for the PF is determined by:

(Reference-SFN + PF_offset) mod T = (T div N)*(UE_ID mod N)

[0097] Index (i_s), indicating the index of the PO is determined by:

i_s = floor (UE_ID/N) mod Ns

[0098] The UE also receives a parameter indicative of the number of PFs within a paging frame group (PFG). The parameter can directly indicate a number of paging frames within a paging frame group (N_G), or it may indicate a duration (T_{PFG}, e.g. in multiples of slots/symbols/SFN). This parameter may be used to determine the number of PFs that a gNB may wish to cluster together for the purposes of paging.

[0099] For example, value of N_G can be set to 1,2,4,8… If it is set to 4, it may indicate that four consecutive paging frames are clustered together for paging.

[0100] For example, value of T_{PFG} can be set to rf2,rf4,rf8… If it is set to rf4, it may indicate that paging frames in four consecutive frames are clustered together for paging.

[0101] The UE may also receive another parameter indicative of how the PFs within a paging frame group are mapped to SFNs. For example, this can be a gap/offset, bitmap, etc.

[0102] For example, value of gap/offset can be set to 1,2,3,4,… If it is set to 1, it can indicate that the gap between consecutive PFs within a PFG is 1. So, if the first PF in the PFG is SFN0, then the next three PFs in the PFG would be in SFN1, SFN2 and SFN3, respectively.

[0103] For example, bitmap can be configured with length = 16,… If bits 0,1,2,3 are set to 1, if the first PF in the PFG is SFN0, it would indicate that the PFs in the PFG would be in SFN0, SFN1, SFN2 and SFN3, respectively.

[0104] For example, bitmap can be configured with length = 16,… If bits 0,2,3,5 are set to 1, if the first PF in the PFG is reference-SFN0, it would indicate that the PFs in the PFG would be in SFN0,SFN2, SFN3 and SFN5, respectively.

[0105] The bitmap can be repeated with a periodicity to cover the default paging cycle to identify the Paging frames within a default paging cycle. For example, with a default paging cycle of rf128, and a length 16 bitmap with bits 0,1,2,3, set to 1, the paging frames would be in slots 0,1,2,3, 16,17,18,19, and so on.

[0106] In certain embodiments, instead of a parameter indicative of the number of PFs within a paging frame group, the UE may receive one or more parameters such as a bitmap, periodicity, etc. that can be utilized to enable the confined/clustered paging mechanism.

[0107] An example is shown in Figure 3. Figure 3 shows two parts, the top illustrates the paging frames in one DRX cycle would be distributed according to the usual paging configuration. If in addition, a parameter indicative of the number of PFs within a paging frame

group (PFG) is also configured, the UE may determine its actual Paging frame based on its reference paging frame and the parameter indicative of the number of PFs within a paging frame group (PFG). For example, UE may determine that its reference PF is the x-th PF belongs to PFG y.

[0108] In some scenarios, it may be desirable to provide more paging capacity in a single PF than allowed by legacy configurations.

[0109] In legacy paging configuration, the *Ns* parameter defines the number of POs per PF, where Ns=1,..4. The UE selects one of the provided POs in its PF using a formula, based e.g. on its UE ID. A formula for PO selection is provided to determine the slot/symbol/monitoring occasion where the paging PDCCH for the UE may be found/monitored. Index (i_s), indicating the index of the selected PO slot/symbol/monitoring occasion in the PO slot/symbol/paging search space/monitoring occasions based on the paging search space list (specified as {0, 4, 5, 9}) is determined by:

$$i_s = \text{floor}(UE_ID/N) \bmod Ns$$

where *N* is the number of total paging frames during the DRX cycle. In certain embodiments, the i_s can be floor (UE_ID) mod Ns.

[0110] In one embodiment, when providing a second paging configuration, the gNB may provide more than 4 POs per PF. In one embodiment, the PO selection formula in the second configuration may be the same formula, but the Ns value is allowed to be larger than 4, e.g. 8 or 12. Furthermore, the position of these POs may be individually and separately controlled with a second configuration parameter as compared to the position of the legacy POs.

[0111] In a related embodiment, the list of PO slots is extended to Ns>4 entries. This may include multiple groups of PO slots per frame, with non-PO slots in-between, in order to provide guaranteed scheduling opportunities for regular data. As a non-limiting example, the PO slot list may be defined as {0, 1, 4, 5, 9, 10, 12, 13} for Ns=8, or some other list where a larger fraction of slot indices 0..14 are included. To allow flexibility in Time Division Duplexing (TDD) Uplink (UL)/Downlink (DL) slot configuration, the effective PO slot list to which the i_s index is applied may be obtained as intersection of the defined PO slot list and the TDD DL slot list.

[0112] In one embodiment, the PO slot list for the second paging configuration is also provided as part of the second configuration, and it may be aligned with current the TDD slot configuration.

[0113] Figure 4 illustrate the operation of a UE 400 and a network node 402 (e.g., gNB) in accordance with one example embodiment of the present disclosure. Optional steps or operations are represented by dashed lines/boxes. It should be noted that details regarding each of the steps of Figure 4 described above are equally applicable here to Figure 4 even though all of those

details are not repeated in the following description of Figure 4. The steps of the procedure of Figure 4 are as follows.

[0114] Operation 404 (Optional): The UE 400 optionally sends capability information to the network node 402, where the capability information indicates whether the UE 400 supports paging monitoring using enhanced paging configuration in accordance with embodiments of the present disclosure. In this example, the UE 400 does support this capability.

[0115] Operation 406 (Optional): The network node 402 sends, and the UE 400 receives, a first paging configuration. The first paging configuration may be, e.g., a legacy paging configuration (e.g., a paging configuration as defined by the current 3GPP Rel-18 specifications).

[0116] Operation 408: The network node 402 sends, and the UE 400 receives, a second paging configuration in accordance with any of the embodiments of the second/new/enhanced paging configuration described herein. As described above, the network node 402 may send the second paging configuration via dedicated signaling to the UE 400 or via broadcast system information that is then read by the UE 400. Details regarding the second paging configuration are provided above and those details are equally applicable here.

[0117] Operation 410: The UE 400 monitors for a paging message in accordance with the first paging configuration and/or the second paging configuration. As described above, in one embodiment, the UE 400 monitors for a paging message using only the second paging configuration is a second paging configuration has been received (and, optionally, is configured in the cell on which paging is being monitored). In another embodiment, the UE 400 monitors for paging message using the first paging configuration and/or the second paging configuration, in accordance with an indication received from the network (e.g., from the network node 402). Details are also provided above for how the UE 400 determines the PF(s) based on the second paging configuration, and those details are equally applicable here to operation 410. In other words, a sub-operation of operation 410 is, in some embodiments, the UE 400 determining the PF(s) based on the second paging configuration (e.g., based on a parameter indicative of the number of PFs in a PF group along with one or more other parameters such as, e.g., T, N, and PF_Offset) (operation 410A).

[0118] Figure 5 shows an example of a communication system 500 in accordance with some embodiments.

[0119] In the example, the communication system 500 includes a telecommunication network 502 that includes an access network 504, such as a Radio Access Network (RAN), and a core network 506, which includes one or more core network nodes 508. The access network 504 includes one or more access network nodes, such as network nodes 510A and 510B (one or more of which may be generally referred to as network nodes 510), or any other similar Third

Generation Partnership Project (3GPP) access nodes or non-3GPP Access Points (APs). Moreover, as will be appreciated by those of skill in the art, a network node is not necessarily limited to an implementation in which a radio portion and a baseband portion are supplied and integrated by a single vendor. Thus, it will be understood that network nodes include disaggregated implementations or portions thereof. For example, in some embodiments, the telecommunication network 502 includes one or more Open-RAN (ORAN) network nodes. An ORAN network node is a node in the telecommunication network 502 that supports an ORAN specification (e.g., a specification published by the O-RAN Alliance, or any similar organization) and may operate alone or together with other nodes to implement one or more functionalities of any node in the telecommunication network 502, including one or more network nodes 510 and/or core network nodes 508.

[0120] Examples of an ORAN network node include an Open Radio Unit (O-RU), an Open Distributed Unit (O-DU), an Open Central Unit (O-CU), including an O-CU Control Plane (O-CU-CP) or an O-CU User Plane (O-CU-UP), a RAN intelligent controller (near-real time or non-real time) hosting software or software plug-ins, such as a near-real time control application (e.g., xApp) or a non-real time control application (e.g., rApp), or any combination thereof (the adjective "open" designating support of an ORAN specification). The network node may support a specification by, for example, supporting an interface defined by the ORAN specification, such as an A1, F1, W1, E1, E2, X2, Xn interface, an open fronthaul user plane interface, or an open fronthaul management plane interface. Moreover, an ORAN access node may be a logical node in a physical node. Furthermore, an ORAN network node may be implemented in a virtualization environment (described further below) in which one or more network functions are virtualized. For example, the virtualization environment may include an O-Cloud computing platform orchestrated by a Service Management and Orchestration Framework via an O-2 interface defined by the O-RAN Alliance or comparable technologies. The network nodes 510 facilitate direct or indirect connection of User Equipment (UE), such as by connecting UEs 512A, 512B, 512C, and 512D (one or more of which may be generally referred to as UEs 512) to the core network 506 over one or more wireless connections.

[0121] Example wireless communications over a wireless connection include transmitting and/or receiving wireless signals using electromagnetic waves, radio waves, infrared waves, and/or other types of signals suitable for conveying information without the use of wires, cables, or other material conductors. Moreover, in different embodiments, the communication system 500 may include any number of wired or wireless networks, network nodes, UEs, and/or any other components or systems that may facilitate or participate in the communication of data and/or signals whether via wired or wireless connections. The communication system 500 may

include and/or interface with any type of communication, telecommunication, data, cellular, radio network, and/or other similar type of system.

[0122] The UEs 512 may be any of a wide variety of communication devices, including wireless devices arranged, configured, and/or operable to communicate wirelessly with the network nodes 510 and other communication devices. Similarly, the network nodes 510 are arranged, capable, configured, and/or operable to communicate directly or indirectly with the UEs 512 and/or with other network nodes or equipment in the telecommunication network 502 to enable and/or provide network access, such as wireless network access, and/or to perform other functions, such as administration in the telecommunication network 502.

[0123] In the depicted example, the core network 506 connects the network nodes 510 to one or more hosts, such as host 516. These connections may be direct or indirect via one or more intermediary networks or devices. In other examples, network nodes may be directly coupled to hosts. The core network 506 includes one more core network nodes (e.g., core network node 508) that are structured with hardware and software components. Features of these components may be substantially similar to those described with respect to the UEs, network nodes, and/or hosts, such that the descriptions thereof are generally applicable to the corresponding components of the core network node 508. Example core network nodes include functions of one or more of a Mobile Switching Center (MSC), Mobility Management Entity (MME), Home Subscriber Server (HSS), Access and Mobility Management Function (AMF), Session Management Function (SMF), Authentication Server Function (AUSF), Subscription Identifier De-Concealing Function (SIDF), Unified Data Management (UDM), Security Edge Protection Proxy (SEPP), Network Exposure Function (NEF), and/or a User Plane Function (UPF).

[0124] The host 516 may be under the ownership or control of a service provider other than an operator or provider of the access network 504 and/or the telecommunication network 502, and may be operated by the service provider or on behalf of the service provider. The host 516 may host a variety of applications to provide one or more service. Examples of such applications include live and pre-recorded audio/video content, data collection services such as retrieving and compiling data on various ambient conditions detected by a plurality of UEs, analytics functionality, social media, functions for controlling or otherwise interacting with remote devices, functions for an alarm and surveillance center, or any other such function performed by a server.

[0125] As a whole, the communication system 500 of Figure 5 enables connectivity between the UEs, network nodes, and hosts. In that sense, the communication system 500 may be configured to operate according to predefined rules or procedures, such as specific standards that include, but are not limited to: Global System for Mobile Communications (GSM); Universal

Mobile Telecommunications System (UMTS); Long Term Evolution (LTE), and/or other suitable Second, Third, Fourth, or Fifth Generation (2G, 3G, 4G, or 5G) standards, or any applicable future generation standard (e.g., Sixth Generation (6G)); Wireless Local Area Network (WLAN) standards, such as the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standards (WiFi); and/or any other appropriate wireless communication standard, such as the Worldwide Interoperability for Microwave Access (WiMax), Bluetooth, Z-Wave, Near Field Communication (NFC) ZigBee, LiFi, and/or any Low Power Wide Area Network (LPWAN) standards such as LoRa and Sigfox.

[0126] In some examples, the telecommunication network 502 is a cellular network that implements 3GPP standardized features. Accordingly, the telecommunication network 502 may support network slicing to provide different logical networks to different devices that are connected to the telecommunication network 502. For example, the telecommunication network 502 may provide Ultra Reliable Low Latency Communication (URLLC) services to some UEs, while providing enhanced Mobile Broadband (eMBB) services to other UEs, and/or massive Machine Type Communication (mMTC)/massive Internet of Things (IoT) services to yet further UEs.

[0127] In some examples, the UEs 512 are configured to transmit and/or receive information without direct human interaction. For instance, a UE may be designed to transmit information to the access network 504 on a predetermined schedule, when triggered by an internal or external event, or in response to requests from the access network 504. Additionally, a UE may be configured for operating in single- or multi-Radio Access Technology (RAT) or multi-standard mode. For example, a UE may operate with any one or combination of WiFi, New Radio (NR), and LTE, i.e. being configured for Multi-Radio Dual Connectivity (MR-DC), such as Evolved UMTS Terrestrial RAN (E-UTRAN) NR - Dual Connectivity (EN-DC).

[0128] In the example, a hub 514 communicates with the access network 504 to facilitate indirect communication between one or more UEs (e.g., UE 512C and/or 512D) and network nodes (e.g., network node 510B). In some examples, the hub 514 may be a controller, router, content source and analytics, or any of the other communication devices described herein regarding UEs. For example, the hub 514 may be a broadband router enabling access to the core network 506 for the UEs. As another example, the hub 514 may be a controller that sends commands or instructions to one or more actuators in the UEs. Commands or instructions may be received from the UEs, network nodes 510, or by executable code, script, process, or other instructions in the hub 514. As another example, the hub 514 may be a data collector that acts as temporary storage for UE data and, in some embodiments, may perform analysis or other processing of the data. As another example, the hub 514 may be a content source. For example,

for a UE that is a Virtual Reality (VR) headset, display, loudspeaker or other media delivery device, the hub 514 may retrieve VR assets, video, audio, or other media or data related to sensory information via a network node, which the hub 514 then provides to the UE either directly, after performing local processing, and/or after adding additional local content. In still another example, the hub 514 acts as a proxy server or orchestrator for the UEs, in particular if one or more of the UEs are low energy IoT devices.

[0129] The hub 514 may have a constant/persistent or intermittent connection to the network node 510B. The hub 514 may also allow for a different communication scheme and/or schedule between the hub 514 and UEs (e.g., UE 512C and/or 512D), and between the hub 514 and the core network 506. In other examples, the hub 514 is connected to the core network 506 and/or one or more UEs via a wired connection. Moreover, the hub 514 may be configured to connect to a Machine-to-Machine (M2M) service provider over the access network 504 and/or to another UE over a direct connection. In some scenarios, UEs may establish a wireless connection with the network nodes 510 while still connected via the hub 514 via a wired or wireless connection. In some embodiments, the hub 514 may be a dedicated hub – that is, a hub whose primary function is to route communications to/from the UEs from/to the network node 510B. In other embodiments, the hub 514 may be a non-dedicated hub – that is, a device which is capable of operating to route communications between the UEs and the network node 510B, but which is additionally capable of operating as a communication start and/or end point for certain data channels.

[0130] Figure 6 shows a UE 600 in accordance with some embodiments. As used herein, a UE refers to a device capable, configured, arranged, and/or operable to communicate wirelessly with network nodes and/or other UEs. Examples of a UE include, but are not limited to, a smart phone, mobile phone, cell phone, Voice over Internet Protocol (VoIP) phone, wireless local loop phone, desktop computer, Personal Digital Assistant (PDA), wireless camera, gaming console or device, music storage device, playback appliance, wearable terminal device, wireless endpoint, mobile station, tablet, laptop, Laptop Embedded Equipment (LEE), Laptop Mounted Equipment (LME), smart device, wireless Customer Premise Equipment (CPE), vehicle, vehicle-mounted or vehicle embedded/integrated wireless device, etc. Other examples include any UE identified by the 3GPP, including a Narrowband Internet of Things (NB-IoT) UE, a Machine Type Communication (MTC) UE, and/or an enhanced MTC (eMTC) UE.

[0131] A UE may support Device-to-Device (D2D) communication, for example by implementing a 3GPP standard for sidelink communication, Dedicated Short-Range Communication (DSRC), Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), or Vehicle-to-Everything (V2X). In other examples, a UE may not necessarily have a user in the sense of a

human user who owns and/or operates the relevant device. Instead, a UE may represent a device that is intended for sale to, or operation by, a human user but which may not, or which may not initially, be associated with a specific human user (e.g., a smart sprinkler controller). Alternatively, a UE may represent a device that is not intended for sale to, or operation by, an end user but which may be associated with or operated for the benefit of a user (e.g., a smart power meter).

[0132] The UE 600 includes processing circuitry 602 that is operatively coupled via a bus 604 to an input/output interface 606, a power source 608, memory 610, a communication interface 612, and/or any other component, or any combination thereof. Certain UEs may utilize all or a subset of the components shown in Figure 6. The level of integration between the components may vary from one UE to another UE. Further, certain UEs may contain multiple instances of a component, such as multiple processors, memories, transceivers, transmitters, receivers, etc.

[0133] The processing circuitry 602 is configured to process instructions and data and may be configured to implement any sequential state machine operative to execute instructions stored as machine-readable computer programs in the memory 610. The processing circuitry 602 may be implemented as one or more hardware-implemented state machines (e.g., in discrete logic, Field Programmable Gate Arrays (FPGAs), Application Specific Integrated Circuits (ASICs), etc.); programmable logic together with appropriate firmware; one or more stored computer programs, general purpose processors, such as a microprocessor or Digital Signal Processor (DSP), together with appropriate software; or any combination of the above. For example, the processing circuitry 602 may include multiple Central Processing Units (CPUs).

[0134] In the example, the input/output interface 606 may be configured to provide an interface or interfaces to an input device, output device, or one or more input and/or output devices. Examples of an output device include a speaker, a sound card, a video card, a display, a monitor, a printer, an actuator, an emitter, a smartcard, another output device, or any combination thereof. An input device may allow a user to capture information into the UE 600. Examples of an input device include a touch-sensitive or presence-sensitive display, a camera (e.g., a digital camera, a digital video camera, a web camera, etc.), a microphone, a sensor, a mouse, a trackball, a directional pad, a trackpad, a scroll wheel, a smartcard, and the like. The presence-sensitive display may include a capacitive or resistive touch sensor to sense input from a user. A sensor may be, for instance, an accelerometer, a gyroscope, a tilt sensor, a force sensor, a magnetometer, an optical sensor, a proximity sensor, a biometric sensor, etc., or any combination thereof. An output device may use the same type of interface port as an input

device. For example, a Universal Serial Bus (USB) port may be used to provide an input device and an output device.

[0135] In some embodiments, the power source 608 is structured as a battery or battery pack. Other types of power sources, such as an external power source (e.g., an electricity outlet), photovoltaic device, or power cell, may be used. The power source 608 may further include power circuitry for delivering power from the power source 608 itself, and/or an external power source, to the various parts of the UE 600 via input circuitry or an interface such as an electrical power cable. Delivering power may be, for example, for charging of the power source 608. Power circuitry may perform any formatting, converting, or other modification to the power from the power source 608 to make the power suitable for the respective components of the UE 600 to which power is supplied.

[0136] The memory 610 may be or be configured to include memory such as Random Access Memory (RAM), Read Only Memory (ROM), Programmable ROM (PROM), Erasable PROM (EPROM), Electrically EPROM (EEPROM), magnetic disks, optical disks, hard disks, removable cartridges, flash drives, and so forth. In one example, the memory 610 includes one or more application programs 614, such as an operating system, web browser application, a widget, gadget engine, or other application, and corresponding data 616. The memory 610 may store, for use by the UE 600, any of a variety of various operating systems or combinations of operating systems.

[0137] The memory 610 may be configured to include a number of physical drive units, such as Redundant Array of Independent Disks (RAID), flash memory, USB flash drive, external hard disk drive, thumb drive, pen drive, key drive, High Density Digital Versatile Disc (HD-DVD) optical disc drive, internal hard disk drive, Blu-Ray optical disc drive, Holographic Digital Data Storage (HDDS) optical disc drive, external mini Dual In-line Memory Module (DIMM), Synchronous Dynamic RAM (SDRAM), external micro-DIMM SDRAM, smartcard memory such as a tamper resistant module in the form of a Universal Integrated Circuit Card (UICC) including one or more Subscriber Identity Modules (SIMs), such as a Universal SIM (USIM) and/or Internet Protocol Multimedia Services Identity Module (ISIM), other memory, or any combination thereof. The UICC may for example be an embedded UICC (eUICC), integrated UICC (iUICC) or a removable UICC commonly known as a 'SIM card.' The memory 610 may allow the UE 600 to access instructions, application programs, and the like stored on transitory or non-transitory memory media, to off-load data, or to upload data. An article of manufacture, such as one utilizing a communication system, may be tangibly embodied as or in the memory 610, which may be or comprise a device-readable storage medium.

[0138] The processing circuitry 602 may be configured to communicate with an access network or other network using the communication interface 612. The communication interface 612 may comprise one or more communication subsystems and may include or be communicatively coupled to an antenna 622. The communication interface 612 may include one or more transceivers used to communicate, such as by communicating with one or more remote transceivers of another device capable of wireless communication (e.g., another UE or a network node in an access network). Each transceiver may include a transmitter 618 and/or a receiver 620 appropriate to provide network communications (e.g., optical, electrical, frequency allocations, and so forth). Moreover, the transmitter 618 and receiver 620 may be coupled to one or more antennas (e.g., the antenna 622) and may share circuit components, software, or firmware, or alternatively be implemented separately.

[0139] In the illustrated embodiment, communication functions of the communication interface 612 may include cellular communication, WiFi communication, LPWAN communication, data communication, voice communication, multimedia communication, short-range communications such as Bluetooth, NFC, location-based communication such as the use of the Global Positioning System (GPS) to determine a location, another like communication function, or any combination thereof. Communications may be implemented according to one or more communication protocols and/or standards, such as IEEE 802.11, Code Division Multiplexing Access (CDMA), Wideband CDMA (WCDMA), GSM, LTE, NR, UMTS, WiMax, Ethernet, Transmission Control Protocol/Internet Protocol (TCP/IP), Synchronous Optical Networking (SONET), Asynchronous Transfer Mode (ATM), Quick User Datagram Protocol Internet Connection (QUIC), Hypertext Transfer Protocol (HTTP), and so forth.

[0140] Regardless of the type of sensor, a UE may provide an output of data captured by its sensors, through its communication interface 612, via a wireless connection to a network node. Data captured by sensors of a UE can be communicated through a wireless connection to a network node via another UE. The output may be periodic (e.g., once every 15 minutes if it reports the sensed temperature), random (e.g., to even out the load from reporting from several sensors), in response to a triggering event (e.g., when moisture is detected, an alert is sent), in response to a request (e.g., a user initiated request), or a continuous stream (e.g., a live video feed of a patient).

[0141] As another example, a UE comprises an actuator, a motor, or a switch related to a communication interface configured to receive wireless input from a network node via a wireless connection. In response to the received wireless input the states of the actuator, the motor, or the switch may change. For example, the UE may comprise a motor that adjusts the control surfaces or rotors of a drone in flight according to the received input or to a robotic arm performing a

medical procedure according to the received input.

[0142] A UE, when in the form of an IoT device, may be a device for use in one or more application domains, these domains comprising, but not limited to, city wearable technology, extended industrial application, and healthcare. Non-limiting examples of such an IoT device are a device which is or which is embedded in: a connected refrigerator or freezer, a television, a connected lighting device, an electricity meter, a robot vacuum cleaner, a voice controlled smart speaker, a home security camera, a motion detector, a thermostat, a smoke detector, a door/window sensor, a flood/moisture sensor, an electrical door lock, a connected doorbell, an air conditioning system like a heat pump, an autonomous vehicle, a surveillance system, a weather monitoring device, a vehicle parking monitoring device, an electric vehicle charging station, a smart watch, a fitness tracker, a head-mounted display for Augmented Reality (AR) or VR, a wearable for tactile augmentation or sensory enhancement, a water sprinkler, an animal- or item-tracking device, a sensor for monitoring a plant or animal, an industrial robot, an Unmanned Aerial Vehicle (UAV), and any kind of medical device, like a heart rate monitor or a remote controlled surgical robot. A UE in the form of an IoT device comprises circuitry and/or software in dependence of the intended application of the IoT device in addition to other components as described in relation to the UE 600 shown in Figure 6.

[0143] As yet another specific example, in an IoT scenario, a UE may represent a machine or other device that performs monitoring and/or measurements and transmits the results of such monitoring and/or measurements to another UE and/or a network node. The UE may in this case be an M2M device, which may in a 3GPP context be referred to as an MTC device. As one particular example, the UE may implement the 3GPP NB-IoT standard. In other scenarios, a UE may represent a vehicle, such as a car, a bus, a truck, a ship, an airplane, or other equipment that is capable of monitoring and/or reporting on its operational status or other functions associated with its operation.

[0144] In practice, any number of UEs may be used together with respect to a single use case. For example, a first UE might be or be integrated in a drone and provide the drone's speed information (obtained through a speed sensor) to a second UE that is a remote controller operating the drone. When the user makes changes from the remote controller, the first UE may adjust the throttle on the drone (e.g., by controlling an actuator) to increase or decrease the drone's speed. The first and/or the second UE can also include more than one of the functionalities described above. For example, a UE might comprise the sensor and the actuator and handle communication of data for both the speed sensor and the actuators.

[0145] Figure 7 shows a network node 700 in accordance with some embodiments. As used herein, network node refers to equipment capable, configured, arranged, and/or operable to

communicate directly or indirectly with a UE and/or with other network nodes or equipment in a telecommunication network. Examples of network nodes include, but are not limited to, APs (e.g., radio APs), Base Stations (BSs) (e.g., radio BSs, Node Bs, evolved Node Bs (eNBs), NR Node Bs (gNBs)), and O-RAN nodes or components of an O-RAN node (e.g., O-RU, O-DU, O-CU).

[0146] Base stations may be categorized based on the amount of coverage they provide (or, stated differently, their transmit power level) and so, depending on the provided amount of coverage, may be referred to as femto base stations, pico base stations, micro base stations, or macro base stations. A base station may be a relay node or a relay donor node controlling a relay. A network node may also include one or more (or all) parts of a distributed radio base station such as centralized digital units, distributed units (e.g., in an O-RAN access node), and/or Remote Radio Units (RRUs), sometimes referred to as Remote Radio Heads (RRHs). Such RRUs may or may not be integrated with an antenna as an antenna integrated radio. Parts of a distributed radio base station may also be referred to as nodes in a Distributed Antenna System (DAS).

[0147] Other examples of network nodes include multiple Transmission Point (multi-TRP) 5G access nodes, Multi-Standard Radio (MSR) equipment such as MSR BSs, network controllers such as Radio Network Controllers (RNCs) or BS Controllers (BSCs), Base Transceiver Stations (BTSs), transmission points, transmission nodes, Multi-Cell/Multicast Coordination Entities (MCEs), Operation and Maintenance (O&M) nodes, Operations Support System (OSS) nodes, Self-Organizing Network (SON) nodes, positioning nodes (e.g., Evolved Serving Mobile Location Centers (E-SMLCs)), and/or Minimization of Drive Tests (MDTs).

[0148] The network node 700 includes processing circuitry 702, memory 704, a communication interface 706, and a power source 708. The network node 700 may be composed of multiple physically separate components (e.g., a NodeB component and an RNC component, or a BTS component and a BSC component, etc.), which may each have their own respective components. In certain scenarios in which the network node 700 comprises multiple separate components (e.g., BTS and BSC components), one or more of the separate components may be shared among several network nodes. For example, a single RNC may control multiple NodeBs. In such a scenario, each unique NodeB and RNC pair may in some instances be considered a single separate network node. In some embodiments, the network node 700 may be configured to support multiple RATs. In such embodiments, some components may be duplicated (e.g., separate memory 704 for different RATs) and some components may be reused (e.g., a same antenna 710 may be shared by different RATs). The network node 700 may also include multiple sets of the various illustrated components for different wireless technologies integrated into

network node 700, for example GSM, WCDMA, LTE, NR, WiFi, Zigbee, Z-wave, Long Range Wide Area Network (LoRaWAN), Radio Frequency Identification (RFID), or Bluetooth wireless technologies. These wireless technologies may be integrated into the same or different chip or set of chips and other components within the network node 700.

[0149] The processing circuitry 702 may comprise a combination of one or more of a microprocessor, controller, microcontroller, CPU, DSP, ASIC, FPGA, or any other suitable computing device, resource, or combination of hardware, software, and/or encoded logic operable to provide, either alone or in conjunction with other network node 700 components, such as the memory 704, to provide network node 700 functionality.

[0150] In some embodiments, the processing circuitry 702 includes a System on a Chip (SOC). In some embodiments, the processing circuitry 702 includes one or more of Radio Frequency (RF) transceiver circuitry 712 and baseband processing circuitry 714. In some embodiments, the RF transceiver circuitry 712 and the baseband processing circuitry 714 may be on separate chips (or sets of chips), boards, or units, such as radio units and digital units. In alternative embodiments, part or all of the RF transceiver circuitry 712 and the baseband processing circuitry 714 may be on the same chip or set of chips, boards, or units.

[0151] The memory 704 may comprise any form of volatile or non-volatile computer-readable memory including, without limitation, persistent storage, solid state memory, remotely mounted memory, magnetic media, optical media, RAM, ROM, mass storage media (for example, a hard disk), removable storage media (for example, a flash drive, a Compact Disk (CD), or a Digital Video Disk (DVD)), and/or any other volatile or non-volatile, non-transitory device-readable, and/or computer-executable memory devices that store information, data, and/or instructions that may be used by the processing circuitry 702. The memory 704 may store any suitable instructions, data, or information, including a computer program, software, an application including one or more of logic, rules, code, tables, and/or other instructions capable of being executed by the processing circuitry 702 and utilized by the network node 700. The memory 704 may be used to store any calculations made by the processing circuitry 702 and/or any data received via the communication interface 706. In some embodiments, the processing circuitry 702 and the memory 704 are integrated.

[0152] The communication interface 706 is used in wired or wireless communication of signaling and/or data between a network node, access network, and/or UE. As illustrated, the communication interface 706 comprises port(s)/terminal(s) 716 to send and receive data, for example to and from a network over a wired connection. The communication interface 706 also includes radio front-end circuitry 718 that may be coupled to, or in certain embodiments a part of, the antenna 710. The radio front-end circuitry 718 comprises filters 720 and amplifiers 722.

The radio front-end circuitry 718 may be connected to the antenna 710 and the processing circuitry 702. The radio front-end circuitry 718 may be configured to condition signals communicated between the antenna 710 and the processing circuitry 702. The radio front-end circuitry 718 may receive digital data that is to be sent out to other network nodes or UEs via a wireless connection. The radio front-end circuitry 718 may convert the digital data into a radio signal having the appropriate channel and bandwidth parameters using a combination of the filters 720 and/or the amplifiers 722. The radio signal may then be transmitted via the antenna 710. Similarly, when receiving data, the antenna 710 may collect radio signals which are then converted into digital data by the radio front-end circuitry 718. The digital data may be passed to the processing circuitry 702. In other embodiments, the communication interface 706 may comprise different components and/or different combinations of components.

[0153] In certain alternative embodiments, the network node 700 does not include separate radio front-end circuitry 718; instead, the processing circuitry 702 includes radio front-end circuitry and is connected to the antenna 710. Similarly, in some embodiments, all or some of the RF transceiver circuitry 712 is part of the communication interface 706. In still other embodiments, the communication interface 706 includes the one or more ports or terminals 716, the radio front-end circuitry 718, and the RF transceiver circuitry 712 as part of a radio unit (not shown), and the communication interface 706 communicates with the baseband processing circuitry 714, which is part of a digital unit (not shown).

[0154] The antenna 710 may include one or more antennas, or antenna arrays, configured to send and/or receive wireless signals. The antenna 710 may be coupled to the radio front-end circuitry 718 and may be any type of antenna capable of transmitting and receiving data and/or signals wirelessly. In certain embodiments, the antenna 710 is separate from the network node 700 and connectable to the network node 700 through an interface or port.

[0155] The antenna 710, the communication interface 706, and/or the processing circuitry 702 may be configured to perform any receiving operations and/or certain obtaining operations described herein as being performed by the network node 700. Any information, data, and/or signals may be received from a UE, another network node, and/or any other network equipment. Similarly, the antenna 710, the communication interface 706, and/or the processing circuitry 702 may be configured to perform any transmitting operations described herein as being performed by the network node 700. Any information, data, and/or signals may be transmitted to a UE, another network node, and/or any other network equipment.

[0156] The power source 708 provides power to the various components of the network node 700 in a form suitable for the respective components (e.g., at a voltage and current level needed for each respective component). The power source 708 may further comprise, or be coupled to,

power management circuitry to supply the components of the network node 700 with power for performing the functionality described herein. For example, the network node 700 may be connectable to an external power source (e.g., the power grid or an electricity outlet) via input circuitry or an interface such as an electrical cable, whereby the external power source supplies power to power circuitry of the power source 708. As a further example, the power source 708 may comprise a source of power in the form of a battery or battery pack which is connected to, or integrated in, power circuitry. The battery may provide backup power should the external power source fail.

[0157] Embodiments of the network node 700 may include additional components beyond those shown in Figure 7 for providing certain aspects of the network node's functionality, including any of the functionality described herein and/or any functionality necessary to support the subject matter described herein. For example, the network node 700 may include user interface equipment to allow input of information into the network node 700 and to allow output of information from the network node 700. This may allow a user to perform diagnostic, maintenance, repair, and other administrative functions for the network node 700.

[0158] Figure 8 is a block diagram of a host 800, which may be an embodiment of the host 516 of Figure 5, in accordance with various aspects described herein. As used herein, the host 800 may be or comprise various combinations of hardware and/or software including a standalone server, a blade server, a cloud-implemented server, a distributed server, a virtual machine, container, or processing resources in a server farm. The host 800 may provide one or more services to one or more UEs.

[0159] The host 800 includes processing circuitry 802 that is operatively coupled via a bus 804 to an input/output interface 806, a network interface 808, a power source 810, and memory 812. Other components may be included in other embodiments. Features of these components may be substantially similar to those described with respect to the devices of previous figures, such as Figures 6 and 7, such that the descriptions thereof are generally applicable to the corresponding components of the host 800.

[0160] The memory 812 may include one or more computer programs including one or more host application programs 814 and data 816, which may include user data, e.g. data generated by a UE for the host 800 or data generated by the host 800 for a UE. Embodiments of the host 800 may utilize only a subset or all of the components shown. The host application programs 814 may be implemented in a container-based architecture and may provide support for video codecs (e.g., Versatile Video Coding (VVC), High Efficiency Video Coding (HEVC), Advanced Video Coding (AVC), Moving Picture Experts Group (MPEG), VP9) and audio codecs (e.g., Free Lossless Audio Codec (FLAC), Advanced Audio Coding (AAC), MPEG, G.711), including

transcoding for multiple different classes, types, or implementations of UEs (e.g., handsets, desktop computers, wearable display systems, and heads-up display systems). The host application programs 814 may also provide for user authentication and licensing checks and may periodically report health, routes, and content availability to a central node, such as a device in or on the edge of a core network. Accordingly, the host 800 may select and/or indicate a different host for Over-The-Top (OTT) services for a UE. The host application programs 814 may support various protocols, such as the HTTP Live Streaming (HLS) protocol, Real-Time Messaging Protocol (RTMP), Real-Time Streaming Protocol (RTSP), Dynamic Adaptive Streaming over HTTP (DASH or MPEG-DASH), etc.

[0161] Figure 9 is a block diagram illustrating a virtualization environment 900 in which functions implemented by some embodiments may be virtualized. In the present context, virtualizing means creating virtual versions of apparatuses or devices which may include virtualizing hardware platforms, storage devices, and networking resources. As used herein, virtualization can be applied to any device described herein, or components thereof, and relates to an implementation in which at least a portion of the functionality is implemented as one or more virtual components. Some or all of the functions described herein may be implemented as virtual components executed by one or more Virtual Machines (VMs) implemented in one or more virtual environments 900 hosted by one or more of hardware nodes, such as a hardware computing device that operates as a network node, UE, core network node, or host. Further, in embodiments in which the virtual node does not require radio connectivity (e.g., a core network node or host), then the node may be entirely virtualized. In some embodiments, the virtualization environment 900 includes components defined by the O-RAN Alliance, such as an O-Cloud environment orchestrated by a Service Management and Orchestration Framework via an O-2 interface.

[0162] Applications 902 (which may alternatively be called software instances, virtual appliances, network functions, virtual nodes, virtual network functions, etc.) are run in the virtualization environment 900 to implement some of the features, functions, and/or benefits of some of the embodiments disclosed herein.

[0163] Hardware 904 includes processing circuitry, memory that stores software and/or instructions executable by hardware processing circuitry, and/or other hardware devices as described herein, such as a network interface, input/output interface, and so forth. Software may be executed by the processing circuitry to instantiate one or more virtualization layers 906 (also referred to as hypervisors or VM Monitors (VMMs)), provide VMs 908A and 908B (one or more of which may be generally referred to as VMs 908), and/or perform any of the functions, features, and/or benefits described in relation with some embodiments described herein. The

virtualization layer 906 may present a virtual operating platform that appears like networking hardware to the VMs 908.

[0164] The VMs 908 comprise virtual processing, virtual memory, virtual networking, or interface and virtual storage, and may be run by a corresponding virtualization layer 906. Different embodiments of the instance of a virtual appliance 902 may be implemented on one or more of the VMs 908, and the implementations may be made in different ways. Virtualization of the hardware is in some contexts referred to as Network Function Virtualization (NFV). NFV may be used to consolidate many network equipment types onto industry standard high volume server hardware, physical switches, and physical storage, which can be located in data centers and customer premise equipment.

[0165] In the context of NFV, a VM 908 may be a software implementation of a physical machine that runs programs as if they were executing on a physical, non-virtualized machine. Each of the VMs 908, and that part of the hardware 904 that executes that VM, be it hardware dedicated to that VM and/or hardware shared by that VM with others of the VMs 908, forms separate virtual network elements. Still in the context of NFV, a virtual network function is responsible for handling specific network functions that run in one or more VMs 908 on top of the hardware 904 and corresponds to the application 902.

[0166] The hardware 904 may be implemented in a standalone network node with generic or specific components. The hardware 904 may implement some functions via virtualization. Alternatively, the hardware 904 may be part of a larger cluster of hardware (e.g., such as in a data center or CPE) where many hardware nodes work together and are managed via management and orchestration 910, which, among others, oversees lifecycle management of the applications 902. In some embodiments, the hardware 904 is coupled to one or more radio units that each include one or more transmitters and one or more receivers that may be coupled to one or more antennas. Radio units may communicate directly with other hardware nodes via one or more appropriate network interfaces and may be used in combination with the virtual components to provide a virtual node with radio capabilities, such as a RAN or a base station. In some embodiments, some signaling can be provided with the use of a control system 912 which may alternatively be used for communication between hardware nodes and radio units.

[0167] Figure 10 shows a communication diagram of a host 1002 communicating via a network node 1004 with a UE 1006 over a partially wireless connection in accordance with some embodiments. Example implementations, in accordance with various embodiments, of the UE (such as the UE 512A of Figure 5 and/or the UE 600 of Figure 6), the network node (such as the network node 510A of Figure 5 and/or the network node 700 of Figure 7), and the host (such as

the host 516 of Figure 5 and/or the host 800 of Figure 8) discussed in the preceding paragraphs will now be described with reference to Figure 10.

[0168] Like the host 800, embodiments of the host 1002 include hardware, such as a communication interface, processing circuitry, and memory. The host 1002 also includes software, which is stored in or is accessible by the host 1002 and executable by the processing circuitry. The software includes a host application that may be operable to provide a service to a remote user, such as the UE 1006 connecting via an OTT connection 1050 extending between the UE 1006 and the host 1002. In providing the service to the remote user, a host application may provide user data which is transmitted using the OTT connection 1050.

[0169] The network node 1004 includes hardware enabling it to communicate with the host 1002 and the UE 1006. The connection 1060 may be direct or pass through a core network (like the core network 506 of Figure 5) and/or one or more other intermediate networks, such as one or more public, private, or hosted networks. For example, an intermediate network may be a backbone network or the Internet.

[0170] The UE 1006 includes hardware and software, which is stored in or accessible by the UE 1006 and executable by the UE's processing circuitry. The software includes a client application, such as a web browser or operator-specific "app" that may be operable to provide a service to a human or non-human user via the UE 1006 with the support of the host 1002. In the host 1002, an executing host application may communicate with the executing client application via the OTT connection 1050 terminating at the UE 1006 and the host 1002. In providing the service to the user, the UE's client application may receive request data from the host's host application and provide user data in response to the request data. The OTT connection 1050 may transfer both the request data and the user data. The UE's client application may interact with the user to generate the user data that it provides to the host application through the OTT connection 1050.

[0171] The OTT connection 1050 may extend via the connection 1060 between the host 1002 and the network node 1004 and via a wireless connection 1070 between the network node 1004 and the UE 1006 to provide the connection between the host 1002 and the UE 1006. The connection 1060 and the wireless connection 1070, over which the OTT connection 1050 may be provided, have been drawn abstractly to illustrate the communication between the host 1002 and the UE 1006 via the network node 1004, without explicit reference to any intermediary devices and the precise routing of messages via these devices.

[0172] As an example of transmitting data via the OTT connection 1050, in operation 1008, the host 1002 provides user data, which may be performed by executing a host application. In some embodiments, the user data is associated with a particular human user interacting with the

UE 1006. In other embodiments, the user data is associated with a UE 1006 that shares data with the host 1002 without explicit human interaction. In operation 1010, the host 1002 initiates a transmission carrying the user data towards the UE 1006. The host 1002 may initiate the transmission responsive to a request transmitted by the UE 1006. The request may be caused by human interaction with the UE 1006 or by operation of the client application executing on the UE 1006. The transmission may pass via the network node 1004 in accordance with the teachings of the embodiments described throughout this disclosure. Accordingly, in operation 1012, the network node 1004 transmits to the UE 1006 the user data that was carried in the transmission that the host 1002 initiated, in accordance with the teachings of the embodiments described throughout this disclosure. In operation 1014, the UE 1006 receives the user data carried in the transmission, which may be performed by a client application executed on the UE 1006 associated with the host application executed by the host 1002.

[0173] In some examples, the UE 1006 executes a client application which provides user data to the host 1002. The user data may be provided in reaction or response to the data received from the host 1002. Accordingly, in operation 1016, the UE 1006 may provide user data, which may be performed by executing the client application. In providing the user data, the client application may further consider user input received from the user via an input/output interface of the UE 1006. Regardless of the specific manner in which the user data was provided, the UE 1006 initiates, in operation 1018, transmission of the user data towards the host 1002 via the network node 1004. In operation 1020, in accordance with the teachings of the embodiments described throughout this disclosure, the network node 1004 receives user data from the UE 1006 and initiates transmission of the received user data towards the host 1002. In operation 1022, the host 1002 receives the user data carried in the transmission initiated by the UE 1006.

[0174] One or more of the various embodiments improve the performance of OTT services provided to the UE 1006 using the OTT connection 1050, in which the wireless connection 1070 forms the last segment. More precisely, the teachings of these embodiments may improve, e.g., power consumption thereby provide related benefits.

[0175] In an example scenario, factory status information may be collected and analyzed by the host 1002. As another example, the host 1002 may process audio and video data which may have been retrieved from a UE for use in creating maps. As another example, the host 1002 may collect and analyze real-time data to assist in controlling vehicle congestion (e.g., controlling traffic lights). As another example, the host 1002 may store surveillance video uploaded by a UE. As another example, the host 1002 may store or control access to media content such as video, audio, VR, or AR which it can broadcast, multicast, or unicast to UEs. As other examples, the host 1002 may be used for energy pricing, remote control of non-time critical electrical load

to balance power generation needs, location services, presentation services (such as compiling diagrams etc. from data collected from remote devices), or any other function of collecting, retrieving, storing, analyzing, and/or transmitting data.

[0176] In some examples, a measurement procedure may be provided for the purpose of monitoring data rate, latency, and other factors on which the one or more embodiments improve. There may further be an optional network functionality for reconfiguring the OTT connection 1050 between the host 1002 and the UE 1006 in response to variations in the measurement results. The measurement procedure and/or the network functionality for reconfiguring the OTT connection 1050 may be implemented in software and hardware of the host 1002 and/or the UE 1006. In some embodiments, sensors (not shown) may be deployed in or in association with other devices through which the OTT connection 1050 passes; the sensors may participate in the measurement procedure by supplying values of the monitored quantities exemplified above, or by supplying values of other physical quantities from which software may compute or estimate the monitored quantities. The reconfiguring of the OTT connection 1050 may include message format, retransmission settings, preferred routing, etc.; the reconfiguring need not directly alter the operation of the network node 1004. Such procedures and functionalities may be known and practiced in the art. In certain embodiments, measurements may involve proprietary UE signaling that facilitates measurements of throughput, propagation times, latency, and the like by the host 1002. The measurements may be implemented in that software causes messages to be transmitted, in particular empty or 'dummy' messages, using the OTT connection 1050 while monitoring propagation times, errors, etc.

[0177] Although the computing devices described herein (e.g., UEs, network nodes, hosts) may include the illustrated combination of hardware components, other embodiments may comprise computing devices with different combinations of components. It is to be understood that these computing devices may comprise any suitable combination of hardware and/or software needed to perform the tasks, features, functions, and methods disclosed herein. Determining, calculating, obtaining, or similar operations described herein may be performed by processing circuitry, which may process information by, for example, converting the obtained information into other information, comparing the obtained information or converted information to information stored in the network node, and/or performing one or more operations based on the obtained information or converted information, and as a result of said processing making a determination. Moreover, while components are depicted as single boxes located within a larger box or nested within multiple boxes, in practice computing devices may comprise multiple different physical components that make up a single illustrated component, and functionality may be partitioned between separate components. For example, a communication interface may

be configured to include any of the components described herein, and/or the functionality of the components may be partitioned between the processing circuitry and the communication interface. In another example, non-computationally intensive functions of any of such components may be implemented in software or firmware and computationally intensive functions may be implemented in hardware.

[0178] In certain embodiments, some or all of the functionality described herein may be provided by processing circuitry executing instructions stored in memory, which in certain embodiments may be a computer program product in the form of a non-transitory computer-readable storage medium. In alternative embodiments, some or all of the functionality may be provided by the processing circuitry without executing instructions stored on a separate or discrete device-readable storage medium, such as in a hardwired manner. In any of those particular embodiments, whether executing instructions stored on a non-transitory computer-readable storage medium or not, the processing circuitry can be configured to perform the described functionality. The benefits provided by such functionality are not limited to the processing circuitry alone or to other components of the computing device, but are enjoyed by the computing device as a whole and/or by end users and a wireless network generally.

[0179] Those skilled in the art will recognize improvements and modifications to the embodiments of the present disclosure. All such improvements and modifications are considered within the scope of the concepts disclosed herein.

[0180] Some example embodiments of the present disclosure are as follows:

GROUP A EMBODIMENTS

[0181] Embodiment 1: A method performed by a User Equipment, UE, (400) for paging monitoring, the method comprising:

receiving (408), from a network node (402), an enhanced paging configuration; and

monitoring (410) for a paging message in accordance with the enhanced paging configuration.

[0182] Embodiment 2: The method of embodiment 1, wherein the enhanced paging configuration comprises information that indicates a number of paging frames in a paging frame group.

[0183] Embodiment 3: The method of embodiment 2, further comprising determining (410A) one or more paging frames for monitoring (410) for a paging message based on the indicated number of paging frames in a paging frame group.

[0184] Embodiment 4: The method of embodiment 3, wherein determining (410A) the one or more paging frames for monitoring (410) for a paging message is further based on one or more additional parameters signaled by the network node (402) (e.g., as part of the enhanced

paging configuration, as part of another paging configuration (e.g., the first paging configuration), or a combination thereof).

[0185] Embodiment 5: The method of embodiment 4, wherein the one or more paging frames are determined in accordance with:

$$(SFN + PF_offset) \bmod T = N_G * (T \operatorname{div} (N/N_G)) * \operatorname{floor}((UE_ID \bmod N)/N_G)) + ((UE_ID \bmod N) \bmod N_G)$$

wherein:

- SFN is a system frame number (e.g., an SFN corresponding to a paging frame),
- PF_offset is an offset derived from the parameter (e.g., nAndPagingFrameOffset) indicated either in the enhanced paging configuration or another paging configuration (e.g., a first paging configuration) on which the enhanced paging configuration is based,
- N_G is a number of paging frames in a paging frame group,
- T is a DRX cycle indicated in broadcast system information,
- N is a number of total paging frames in T and is derived from a parameter (e.g., nAndPagingFrameOffset) indicated in either in the enhanced paging configuration or another paging configuration (e.g., a first paging configuration) on which the enhanced paging configuration is based, and
- UE_ID is an identity of the UE 400 (e.g., a 5G-S-TMSI of the UE 400).

[0186] Embodiment 6: The method of embodiment 4, wherein the one or more paging frames are determined in accordance with:

$$(SFN + PF_offset) \bmod T = N_G * (T \operatorname{div} (N/N_G)) * \operatorname{floor}((UE_ID \bmod N)/N_G)) + gap * ((UE_ID \bmod N) \bmod N_G)$$

wherein:

- SFN is a system frame number (e.g., an SFN corresponding to a paging frame),
- PF_offset is an offset derived from the parameter (e.g., nAndPagingFrameOffset) indicated either in the enhanced paging configuration or another paging configuration (e.g., a first paging configuration) on which the enhanced paging configuration is based,
- N_G is a number of paging frames in a paging frame group,
- T is a DRX cycle indicated in broadcast system information,
- N is a number of total paging frames in T and is derived from a parameter (e.g., nAndPagingFrameOffset) indicated in either in the enhanced paging configuration or another paging configuration (e.g., a first paging configuration) on which the enhanced paging configuration is based,

- UE_ID is an identity of the UE 400 (e.g., a 5G-S-TMSI of the UE 400), and
- gap is a size (e.g., number of time slots (e.g., subframes or OFDM symbols)) of a gap between adjacent paging frames of a paging frame group.

[0187] Embodiment 7: The method of any of embodiments 1 to 6, further comprising receiving (406) a first paging configuration.

[0188] Embodiment 8: The method of embodiment 7, wherein the first paging configuration is a legacy paging configuration.

[0189] Embodiment 9: The method of embodiment 7 or 8, wherein the first paging configuration comprises information that configures a number of paging occasions for a paging frame.

[0190] Embodiment 10: The method of any of embodiments 7 to 9, wherein, in accordance with the first paging occasion, a SFN for a paging frame is determined by:

$$(SFN + PF_offset) \bmod T = (T \operatorname{div} N)*(UE_ID \bmod N), \text{ and}$$

an index (i_s) indicating an index of a paging occasion is determined by:

$$i_s = floor(UE_ID/N) \bmod Ns,$$

wherein:

T is a DRX cycle indicated in broadcast system information,

N is a number of total paging frames in T and is derived from a parameter (e.g., nAndPagingFrameOffset) indicated in the first paging configuration,

Ns is a number of paging occasions for a paging frame and is indicated in the first paging configuration,

PF_offset is an offset derived from the parameter (e.g., nAndPagingFrameOffset) indicated in the first paging configuration, and

UE_ID is an identity of the UE 400 (e.g., a 5G-S-TMSI of the UE 400).

[0191] Embodiment 11: The method of any of embodiments 7 to 10, wherein the enhanced paging configuration is independent of the first paging configuration.

[0192] Embodiment 12: The method of any of embodiments 7 to 10, wherein the enhanced paging configuration is based on (e.g., dependent on) the first paging configuration.

[0193] Embodiment 13: The method of any of embodiments 7 to 12, wherein the enhanced paging configuration comprises one or more parameters that are not included in the first paging configuration.

[0194] Embodiment 14: The method of embodiment 13, wherein the one or more parameters that are not included in the first paging configuration comprises a parameter that indicates a number of paging frames in a paging frame group.

[0195] Embodiment 15: The method of any of embodiments 7 to 14, wherein the enhanced paging configuration comprises information that indicates a new value (i.e., the new value or a delta value) for at least one parameter comprised in the first paging configuration.

[0196] Embodiment 16: The method of any of embodiments 7 to 15, wherein one or more characteristics of the enhanced paging configuration are different than those of the first paging configuration, the one or more characteristics comprising any one or more of the following:

one or more scheduling characteristics (e.g., PDSCH time domain resource allocation);

CORESET and/or search space;

one or more encoding characteristics (e.g., TB scaling value, RNTI used to encode the DCI associated to the enhanced paging configuration).

[0197] Embodiment 17: The method of any of embodiments 1 to 16, wherein receiving (408) the enhanced paging configuration comprises receiving (408) the enhanced paging configuration via dedicated signaling or via broadcast system information.

[0198] Embodiment 18: The method of any of the previous embodiments, further comprising:

providing user data; and

forwarding the user data to a host via the transmission to the network node.

GROUP B EMBODIMENTS

[0199] Embodiment 19: A method performed by a network node (402) for configuration of paging monitoring, the method comprising:

sending (408) an enhanced paging configuration to a User Equipment, UE, (400).

[0200] Embodiment 20: The method of embodiment 19, wherein the enhanced paging configuration comprises information that indicates a number of paging frames in a paging frame group.

[0201] Embodiment 21: The method of embodiment 20, wherein one or more paging frames for UE paging monitoring are based on the indicated number of paging frames in a paging frame group.

[0202] Embodiment 22: The method of embodiment 21, wherein the one or more paging frames for UE paging monitoring are further based on one or more additional parameters signaled by the network node (402) (e.g., as part of the enhanced paging configuration, as part of another paging configuration (e.g., the first paging configuration), or a combination thereof).

[0203] Embodiment 23: The method of embodiment 22, wherein the one or more paging frames are determined in accordance with:

$$(\mathbf{SFN} + \text{PF_offset}) \bmod T =$$

$$N_G * (T \operatorname{div} (N/ N_G)) * \text{floor}((\text{UE_ID} \bmod N)/ N_G)) + ((\text{UE_ID} \bmod N) \bmod N_G)$$

wherein:

- SFN is a system frame number (e.g., an SFN corresponding to a paging frame),
- PF_offset is an offset derived from the parameter (e.g., nAndPagingFrameOffset) indicated either in the enhanced paging configuration or another paging configuration (e.g., a first paging configuration) on which the enhanced paging configuration is based,
- N_G is a number of paging frames in a paging frame group,
- T is a DRX cycle indicated in broadcast system information,
- N is a number of total paging frames in T and is derived from a parameter (e.g., nAndPagingFrameOffset) indicated in either in the enhanced paging configuration or another paging configuration (e.g., a first paging configuration) on which the enhanced paging configuration is based, and
- UE_ID is an identity of the UE 400 (e.g., a 5G-S-TMSI of the UE 400).

[0204] Embodiment 24: The method of embodiment 22, wherein the one or more paging frames are determined in accordance with:

$$(\mathbf{SFN} + PF_offset) \bmod T = N_G * (T \operatorname{div} (N/N_G)) * \operatorname{floor}((UE_ID \bmod N)/N_G)) + gap * ((UE_ID \bmod N) \bmod N_G)$$

wherein:

- SFN is a system frame number (e.g., an SFN corresponding to a paging frame),
- PF_offset is an offset derived from the parameter (e.g., nAndPagingFrameOffset) indicated either in the enhanced paging configuration or another paging configuration (e.g., a first paging configuration) on which the enhanced paging configuration is based,
- N_G is a number of paging frames in a paging frame group,
- T is a DRX cycle indicated in broadcast system information,
- N is a number of total paging frames in T and is derived from a parameter (e.g., nAndPagingFrameOffset) indicated in either in the enhanced paging configuration or another paging configuration (e.g., a first paging configuration) on which the enhanced paging configuration is based,
- UE_ID is an identity of the UE 400 (e.g., a 5G-S-TMSI of the UE 400), and
- gap is a size (e.g., number of time slots (e.g., subframes or OFDM symbols)) of a gap between adjacent paging frames of a paging frame group.

[0205] Embodiment 25: The method of any of embodiments 19 to 24, further comprising sending (406) a first paging configuration to the UE (400).

[0206] Embodiment 26: The method of embodiment 25, wherein the first paging configuration is a legacy paging configuration.

[0207] Embodiment 27: The method of embodiment 25 or 26, wherein the first paging configuration comprises information that configures a number of paging occasions for a paging frame.

[0208] Embodiment 28: The method of any of embodiments 25 to 27, wherein, in accordance with the first paging occasion, a SFN for a paging frame is determined by:

(SFN + PF_offset) mod T = (T div N)*(UE_ID mod N), and

an index (i_s) indicating an index of a paging occasion is determined by:

i_s = floor (UE_ID/N) mod Ns,

wherein:

T is a DRX cycle indicated in broadcast system information,

N is a number of total paging frames in T and is derived from a parameter (e.g., nAndPagingFrameOffset) indicated in the first paging configuration,

Ns is a number of paging occasions for a paging frame and is indicated in the first paging configuration,

PF_offset is an offset derived from the parameter (e.g., nAndPagingFrameOffset) indicated in the first paging configuration, and

UE_ID is an identity of the UE 400 (e.g., a 5G-S-TMSI of the UE 400).

[0209] Embodiment 29: The method of any of embodiments 25 to 28, wherein the enhanced paging configuration is independent of the first paging configuration.

[0210] Embodiment 30: The method of any of embodiments 25 to 28, wherein the enhanced paging configuration is based on (e.g., dependent on) the first paging configuration.

[0211] Embodiment 31: The method of any of embodiments 25 to 30, wherein the enhanced paging configuration comprises one or more parameters that are not included in the first paging configuration.

[0212] Embodiment 32: The method of embodiment 31, wherein the one or more parameters that are not included in the first paging configuration comprises a parameter that indicates a number of paging frames in a paging frame group.

[0213] Embodiment 33: The method of any of embodiments 25 to 32, wherein the enhanced paging configuration comprises information that indicates a new value (i.e., the new value or a delta value) for at least one parameter comprised in the first paging configuration.

[0214] Embodiment 34: The method of any of embodiments 25 to 33, wherein one or more characteristics of the enhanced paging configuration are different than those of the first paging configuration, the one or more characteristics comprising any one or more of the following:

one or more scheduling characteristics (e.g., PDSCH time domain resource allocation);

CORESET and/or search space;

one or more encoding characteristics (e.g., TB scaling value, RNTI used to encode the DCI associated to the enhanced paging configuration).

[0215] Embodiment 35: The method of any of embodiments 19 to 34, wherein sending (408) the enhanced paging configuration comprises sending (408) the enhanced paging configuration via dedicated signaling or via broadcast system information.

[0216] Embodiment 36: The method of any of the previous embodiments, further comprising:

obtaining user data; and

forwarding the user data to a host or a user equipment.

GROUP C EMBODIMENTS

[0217] Embodiment 37: A user equipment comprising:

processing circuitry configured to perform any of the operations of any of the Group A embodiments; and

power supply circuitry configured to supply power to the processing circuitry.

[0218] Embodiment 38: A network node comprising:

processing circuitry configured to perform any of the operations of any of the Group B embodiments; and

power supply circuitry configured to supply power to the processing circuitry.

[0219] Embodiment 39: A user equipment (UE) comprising:

an antenna configured to send and receive wireless signals;

radio front-end circuitry connected to the antenna and to processing circuitry, and configured to condition signals communicated between the antenna and the processing circuitry;

the processing circuitry being configured to perform any of the operations of any of the Group A embodiments;

an input interface connected to the processing circuitry and configured to allow input of information into the UE to be processed by the processing circuitry;

an output interface connected to the processing circuitry and configured to output information from the UE that has been processed by the processing circuitry; and

a battery connected to the processing circuitry and configured to supply power to the UE.

[0220] Those skilled in the art will recognize improvements and modifications to the embodiments of the present disclosure. All such improvements and modifications are considered within the scope of the concepts disclosed herein.

CLAIMS

1. A method performed by a User Equipment, UE, (400) for paging monitoring, the method comprising:

receiving (408) an enhanced paging configuration from a network node (402), the enhanced paging configuration comprising a parameter that defines a number of paging occasions within a paging frame as one of a set of predefined values comprising at least one value that is greater than 4; and

monitoring (410) for a paging message in accordance with the enhanced paging configuration.

2. The method of claim 1, wherein the set of predefined values from which the number of paging occasions within a paging frame is defined comprises the value of 8.

3. The method of any of claims 1 to 2, further comprising receiving (406) a first paging configuration.

4. The method of claim 3, wherein the first paging configuration is a legacy paging configuration.

5. The method of any of claims 3 and 4, wherein the enhanced paging configuration is based on the first paging configuration.

6. The method of claim 5, wherein one or more parameters of the first paging configuration may further define the enhanced paging configuration such that the paging frames and/or paging occasions defined by the first paging configuration do not overlap with the paging frames and/or paging occasions defined by the enhanced paging configuration.

7. The method of claim 6, wherein monitoring for paging according to the enhanced paging configuration comprises monitoring for paging according to the enhanced paging configuration using a paging frame offset parameter given by the first paging configuration as an offset in a determination of paging frame.

8. The method of any of claims 3 and 4, wherein the enhanced paging configuration is independent of the first paging configuration.

9. The method of any of claims 3 to 7, wherein the enhanced paging configuration comprises one or more parameters that over-ride one or more corresponding parameters in the first paging configuration.

10. The method of any of claims 3 to 7, wherein the enhanced paging configuration comprises information that indicates a new value for at least one parameter comprised in the first paging configuration.

11. The method of any of claims 3 to 7, wherein the enhanced paging configuration comprises one or more parameters that are not included in the first paging configuration.

12. The method of claim 11, wherein the one or more parameters that are not included in the first paging configuration comprises a parameter that indicates a number of paging frames in a paging frame group.

13. The method of any of claims 3 to 12, wherein one or more characteristics of the enhanced paging configuration are different than those of the first paging configuration, the one or more characteristics comprising any one or more of the following:

one or more scheduling characteristics;

Control Resource Set, CORESET, and/or search space;

one or more encoding characteristics.

14. The method of any of claims 3 to 13, wherein the UE monitors for a paging message in paging frames and paging occasions according to the enhanced paging configuration and does not monitor for a paging message in paging frames and paging occasions according to the first paging configuration.

15. The method of any of claims 3 to 13, wherein the UE determines which of the first and enhanced paging configurations to use.

16. The method of claim 15, wherein the UE determines which of the first and enhanced paging configuration to use based on an indication received from a network node.

17. The method of claim 15, wherein the UE determines which of the first and enhanced paging configuration to use based on a defined prioritization scheme.

18. The method of any of claims 1 to 17, wherein receiving (408) the enhanced paging configuration comprises receiving (408) the enhanced paging configuration via dedicated signaling or via broadcast system information.

19. The method of any of claims 1 to 18, wherein the enhanced paging configuration further comprises information that indicates a number of paging frames in a paging frame group.

20. The method of claim 19, further comprising determining (410A) one or more paging frames for monitoring (410) for a paging message based on the indicated number of paging frames in a paging frame group.

21. The method of claim 20, wherein determining (410A) the one or more paging frames for monitoring (410) for a paging message is further based on one or more additional parameters signaled by the network node (402).

22. The method of claim 21, wherein the one or more paging frames are determined in accordance with:

$$(SFN + PF_offset) \bmod T =$$

$$N_G * (T \operatorname{div} (N/ N_G)) * \operatorname{floor}((UE_ID \bmod N)/ N_G) + ((UE_ID \bmod N) \bmod N_G)$$

wherein:

SFN is a system frame number,

PF_offset is an offset derived from a parameter indicated either in the enhanced paging configuration or another paging configuration on which the enhanced paging configuration is based,

N_G is a number of paging frames in a paging frame group,

T is a DRX cycle indicated in broadcast system information,

N is a number of total paging frames in T and is derived from a parameter indicated in either in the enhanced paging configuration or another paging configuration on which the enhanced paging configuration is based, and

UE_ID is an identity of the UE.

23. The method of claim 21, wherein the one or more paging frames are determined in accordance with:

$$(SFN + PF_offset) \bmod T =$$

N_G *(T div (N/ N_G))*floor((UE_ID mod N)/ N_G) + gap*((UE_ID mod N) mod N_G)

wherein:

SFN is a system frame number,

PF_offset is an offset derived from a parameter indicated either in the enhanced paging configuration or another paging configuration on which the enhanced paging configuration is based,

N_G is a number of paging frames in a paging frame group,

T is a DRX cycle indicated in broadcast system information,

N is a number of total paging frames in T and is derived from a parameter indicated in either in the enhanced paging configuration or another paging configuration on which the enhanced paging configuration is based,

UE_ID is an identity of the UE, and

gap is a size of a gap between adjacent paging frames of a paging frame group.

24. The method of claim 21, wherein the one or more paging frames are determined in accordance with:

(SFN + PF_offset) mod T =

N_G *(T div (N/ N_G))*floor((UE_ID mod N)/ N_G) + F (((UE_ID mod N) mod N_G))

wherein:

F(0) = 0, F(1) = 1, F(2)=3, F(3) = 4;

SFN is a system frame number,

PF_offset is an offset derived from a parameter indicated either in the enhanced paging configuration or another paging configuration on which the enhanced paging configuration is based,

N_G is a number of paging frames in a paging frame group,

T is a DRX cycle indicated in broadcast system information,

N is a number of total paging frames in T and is derived from a parameter indicated in either in the enhanced paging configuration or another paging configuration on which the enhanced paging configuration is based, and

UE_ID is an identity of the UE.

25. The method of claim 21, wherein the one or more paging frames are determined in accordance with a reference SFN determined by:

(Reference-SFN + PF_offset) mod T = (T div N)*(UE_ID mod N), and

an index (i_s) indicating an index of a paging occasion is determined by:

i_s = floor (UE_ID/N) mod Ns,

where:

T is a DRX cycle indicated in broadcast system information,

N is a number of total paging frames in T and is derived from a parameter indicated in the first paging configuration,

Ns is a number of paging occasions for a paging frame and is indicated in a first paging configuration,

PF_offset is an offset derived from the parameter indicated in the first paging configuration, and

UE_ID is an identity of the UE; and

determining the one or more PFs comprises determining the number of PFs based on the reference SFN and a parameter, comprised in the enhanced paging configuration, that indicates the number of PFs within a paging frame group, PFG.

26. A User Equipment, UE, (400) for paging monitoring, the UE (400) adapted to:

receive (408), from a network node (402), an enhanced paging configuration that configures the UE (400) with a parameter that defines a number of paging occasions within a paging frame as one of a set of predefined values comprising at least one value that is greater than 4; and

monitor (410) for a paging message in accordance with the enhanced paging configuration.

27. The UE (400) of claim 26, further adapted to perform the method of any of claims 2 to 25.

28. A User Equipment, UE, (400; 600) for paging monitoring, the UE (400; 600) comprising:

a communication interface (612) comprising a transmitter (618) and a receiver (620); and

processing circuitry (620) associated with the communication interface (612), the processing circuitry (620) configured to cause the UE (400; 600) to:

receive (408), from a network node (402), an enhanced paging configuration that configures the UE (400) with a parameter that defines a number of paging occasions within a paging frame as one of a set of predefined values comprising at least one value that is greater than 4; and

monitor (410) for a paging message in accordance with the enhanced paging configuration.

29. The UE (400; 600) of claim 28, wherein the processing circuitry (602) is further configured to cause the UE (400; 600) to perform the method of any of claims 2 to 25.

30. A method performed by a network node (402) for configuration of paging monitoring, the method comprising:

sending (408) an enhanced paging configuration to a User Equipment, UE, (400), the enhanced paging configuration comprises a parameter that defines a number of paging occasions within a paging frame as one of a set of predefined values comprising at least one value that is greater than 4.

31. The method of claim 30, wherein the set of predefined values from which the number of paging occasions within a paging frame is defined comprises the value of 8.

32. The method of any of claims 30 and 31, further comprising sending (406) a first paging configuration to the UE (400).

33. The method of claim 32, wherein the first paging configuration is a legacy paging configuration.

34. The method of any of claims 32 to 33, wherein the enhanced paging configuration is based on the first paging configuration.

35. The method of any of claims 32 to 33, wherein the enhanced paging configuration comprises one or more parameters that over-ride one or more corresponding parameters in the first paging configuration.

36. The method of any of claims 32 to 33, wherein the enhanced paging configuration comprises information that indicates a new value for at least one parameter comprised in the first paging configuration.

37. The method of any of claims 32 to 33, wherein the enhanced paging configuration comprises one or more parameters that are not included in the first paging configuration.

38. The method of claim 37, wherein the one or more parameters that are not included in the

first paging configuration comprises a parameter that indicates a number of paging frames in a paging frame group.

39. The method of claim 30, wherein the enhanced paging configuration comprises information that indicates a number of paging frames in a paging frame group.

40. The method of any of claims 30 to 39, wherein sending (408) the enhanced paging configuration comprises sending (408) the enhanced paging configuration via dedicated signaling or via broadcast system information.

41. The method of claim 30, wherein the network node receives, in a paging information container, an indication of a type of paging configuration to be used for paging the UE, wherein the type of paging configuration is either the enhanced paging configuration or a legacy paging configuration.

42. The method of claim 41, wherein the indication of the type of paging configuration to be used for paging the UE comprises any one or more of the following:

a bit that indicates that the UE supports the enhanced paging configuration;

an integer that indicates a number of paging configuration types supported by the UE.

a bitmap that indicates the paging configuration types that the UE supports;

an enumerated parameter that refers to a corresponding paging configuration type or a string that contains the paging configuration type(s) supported by the UE.

43. A network node (402) for configuration of paging monitoring, the network node (402) adapted to:

send (408) an enhanced paging configuration to a User Equipment, UE, (400), the enhanced paging configuration comprises a parameter that defines a number of paging occasions within a paging frame as one of a set of predefined values comprising at least one value that is greater than 4.

44. The network node of claim 43, further adapted to perform the method of any of claims 31 to 42.

45. A network node (402; 700) for configuration of paging monitoring, the network node (402; 700) comprising processing circuitry (702) configured to cause the network node (402;

700) to:

send (408) an enhanced paging configuration to a User Equipment, UE, (400), the enhanced paging configuration comprises a parameter that defines a number of paging occasions within a paging frame as one of a set of predefined values comprising at least one value that is greater than 4.

46. The network node of claim 45, wherein the processing circuitry (702) is further configured to cause the network node (402; 700) to perform the method of any of claims 31 to 42.