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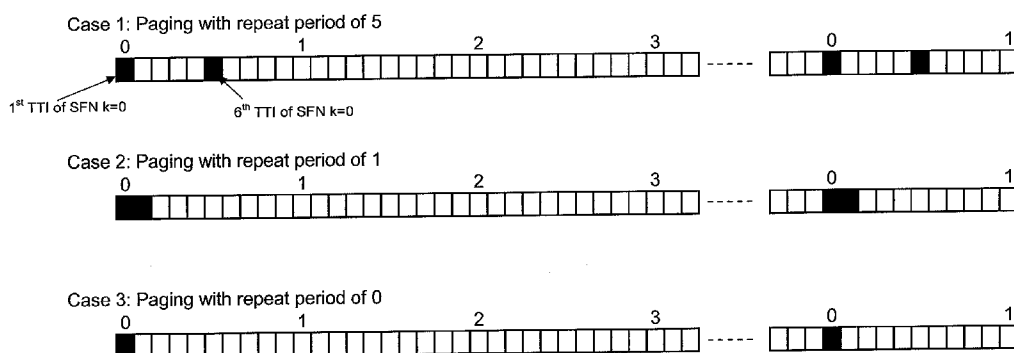


Figure 2

(57) Abstract: There is designated a (plural) number m of time intervals of a frame during which a user equipment is to monitor for a page. A parameter is set that specifies a set of the time intervals of the frame. A page is placed for the user equipment within at least one of the time intervals of the set of time intervals of the frame. The user equipment determines a frame in which to monitor for a page, determines from a parameter wirelessly received from a network a specified set of time intervals of the frame during which to monitor for a page (there are a plural number m of time intervals in the set), and monitors the set of time intervals until at least one of: a page is successfully received; or all of the plural number m of time intervals in the set have been monitored for the page.

ENHANCED PAGING TRANSMISSION AND RECEPTION**TECHNICAL FIELD:**

[0001] The teachings herein relate generally to communications in wireless networks, particularly to paging communications between the network and portable user equipment accessing the network.

BACKGROUND:

[0002] This section is intended to provide a background or context to the invention that is recited in the claims. The description herein may include concepts that could be pursued, but are not necessarily ones that have been previously conceived or pursued. Therefore, unless otherwise indicated herein, what is described in this section is not prior art to the description and claims in this application and is not admitted to be prior art by inclusion in this section.

[0003] The following abbreviations and terms are herewith defined:

3GPP	third generation partnership project
BCH	broadcast channel
C-RNTI	cell radio network temporary identifier
DL	downlink
DRX	discontinuous reception
PCH	paging channel
E-UTRAN	evolved UTRAN (also known as LTE or 3.9G)
IMSI	international mobile subscriber identity
LTE	long term evolution of 3GPP
Node B/eNB	base station or similar network access node
P-RNTI	paging radio network temporary identifier
RACH	random access channel
RRC	radio resource control
TTI	transmission time interval
UE	user equipment (e.g., mobile equipment/station)
UL	uplink
UMTS	universal mobile telecommunications system
UTRAN	UMTS terrestrial radio access network

[0004] For power consumption purposes, many cellular radio systems provide that a UE operates in a reduced power mode (also termed an idle mode) during specified periods and 'wakes' at pre-determined times to listen whether it is being paged. This is generally referred to as discontinuous reception DRX. The network processing a call that is incoming to the idle UE sends a page during that predetermined time between the UE's DRX periods, the UE wakes to receive the page or paging indication and then configures itself to receive the substance of the

page (e.g., the call itself, or if only a paging indication is received in the first instance it configures itself to receive the page and then contact the network to receive the call to which the page relates).

[0005] This basic arrangement has various implementations in different cellular systems. For example, the GERAN system uses a paging period (see 3GPP TS 45.002) and legacy UTRAN (3G) uses paging and idle mode DRX (see 3GPP TS 25.331 and TS 25.304). In UTRAN (3G) the solution for the distribution for paging different UEs has been based on a separate channel, termed the PICH or paging indicator control channel, where the individual UEs are assigned to specific PICH bit positions by a mod formula with the UE's IMSI. The page itself is then sent on a paging channel PCH. A description of this system may be seen at co-owned US Patent No. 6,983,158. In UTRAN the existence of a separate paging channel PCH means the paging does not use the general DL resources that are used for data (which includes voice or other user data). In E-UTRAN, there is no PICH and the E-UTRAN paging channel PACH is mapped to a downlink synchronization channel DL-SCH with data for other UEs.

[0006] Specific adaptations of paging signaling in view of the DRX period that are specifically advantageous for use in an E-UTRAN system are detailed in co-owned provisional patent application serial numbers 60/939,373 ("Apparatus, Method and Computer Program Product Providing Idle Mode Discontinuous Reception", filed June 19, 2007) and 60/964,628 ("Apparatus, Method and Computer Program Product Providing Idle Mode Discontinuous Reception", filed August 14, 2007), both of which are now combined into PCT/IB2008/052429 filed June 19, 2008. The teachings of this disclosure are similarly advantageous for use in an E-UTRAN system though not limited thereto.

[0007] Figure 1 is a general overview of the DRX concept in E-UTRAN for a single mobile terminal/user equipment. The physical downlink control channel PDCCH gives resource allocations (an allocation table AT) to multiple mobile terminals for resources in the uplink and downlink shared channels SCHs (shown as packet data channel PDCH, which Figure 1 implies to include both UL and DL traffic channels as scheduled by the PDCCH). More than one consecutive PDCCH may be used (the duty cycle or 'on-duration' for the RRC-connected mode DRX), but the overall schedule repeats after each DRX. Different UEs have their PDCCHs and PDCHs at different times as compared to the one shown in Figure 1 so as to distribute the pages, and data, in time across the different UEs. The UE is in a low-power state during the

DRX, and wakes at specified times during the DRX (which may extend for several seconds) to listen for its paging indication. 3GPP TS36.300 section 12 generally describes rules for when UE's in the RRC-CONNECTED mode shall be available for scheduling (i.e. the UE shall receive and decode PDCCH for possible scheduling information). Application serial number 60/939,373, referenced above, describes a DRX for idle mode, when the UE in RRC-IDLE mode shall wake up and receive PDCCH for a possible paging message.

[0008] The LTE radio access network eNBs broadcast system information for UEs/mobile terminals. System Information consists of NAS (Non Access Stratum) and AS (Access Stratum) system information. The AS part includes, among other information, idle and active mode system information which is needed in accessing the network including neighbor RAT and neighbor channel information and configuration of terminal measurements to be used in idle and active modes. The NAS portion includes, among other information, parameters of the location area LA, tracking area TA, public land mobile network PLMN identity and PLMN types that may be reached from the serving radio access technology RAT.

[0009] The UE receives/reads the relevant system information of the serving eNB before accessing the system for several reasons. The system information enables the UE to optimize the radio access, to recognize if the cell access is restricted by the operator, and to determine if the terminal has access rights in the cell. The PLMN identity information tells if the network is the home network or a visited network, and gives the UE additional information. But even if the UE has no need to access the system, it still needs to synchronize to the DL-SCH and align to the idle mode DRX of the eNB in order to receive possible paging messages from network.

[0010] The idle mode DRX period must be known to the UE and the eNB so that they both have a synchronized paging occasion. Additionally, if grouping of UE paging messages is applied, there are further parameters concerning grouping information that all of the grouped UEs need for their idle mode. The current assumption in LTE is that paging indications are sent in the L1/L2 control channel (e.g., PDCCH, see Figure 1) using a dedicated RNTI value (termed P-RNTI or paging group RNTI/PG-RNTI, but a C-RNTI may be used as well in other radio technology systems). The UEs having a paging occasion at a predetermined time then check the L1/L2 control channel for the occurrence of the dedicated RNTI. If a P-RNTI match is found, the UE or group of UEs identified by it proceed to read the paging message (e.g., on the paging channel PCH). Allocation for PCH is mapped to the DL-SCH.

[0011] For mobile terminating calls in E-UTRAN, the termination of incoming data packets for UEs in the LTE-IDLE mode triggers the paging and the distribution of paging over all cells of the TA that the UE is registered to. In E-UTRAN, a paging message is also transmitted on the PCH, a separate downlink transport channel as in UTRAN. The PCH is transmitted over the entire cell. The transmission of PCH is associated with transmission of physical-layer generated paging indicators (PI is used herein as a generic term, in E-UTRAN the PI is proposed to be a paging radio node temporary identifier P-RNTI or similar), to support DRX for power saving. The PCH includes the actual paging information and is mapped on the DL-SCH, and the mapping is known from the scheduling information in the PDCCH.

[0012] The UEs may or may not be arranged in paging groups with other UEs, so a PI may be specified for a certain group of UEs or all UEs. UEs in the LTE-IDLE mode then wake up every paging occasion, defined by the DRX rule and specific to each UE (or UE group), and listen for their PI. Those who receive a PI in their paging occasion then further listen to the PCH afterwards to find out if they are actually paged. The precise UE identity and the cause of the paged UE(s) is found on PCH.

[0013] One particular distinction between E-UTRAN and previous generation mobile networks is that the eNB in E-UTRAN autonomously controls its own radio resources, and so the eNB has its own radio resource scheduler. Consequently, what were widely spaced transmissions in certain legacy networks may be more tightly linked in E-UTRAN due to the shorter time lag in scheduling actual resources. For example, in UTRAN, the PI(s) and PCH are transmitted over a system frame of 10ms and the PCH frame is shifted after the PI frame by 2ms. But in E-UTRAN both the PI and the PCH for a single UE may be transmitted in the same TTI of 1ms. The PI is sent, for example, in a so-called allocation table on a physical downlink shared control channel (each instance of the PDCCH is considered an allocation table) within a first few (one, two or three) orthogonal frequency division multiplexed (OFDM) symbols and the PCH is sent later in some of the following OFDM symbols within that same 1-ms TTI. The PI may also take the form of a cell-specific radio network temporary identifier (C-RNTI or P-RNTI or PG-RNTI as noted above) which is reserved for indicating assigned resources for paging in the allocation table/PDCCH. The resources on PDCH (DL-SCH) assigned to be used for transmitting the actual PCH, may then possibly be indicated in PDCCH using the P-RNTI as allocation table entry. Alternatively the resource allocation is fixed.

[0014] Relevant specifications for UTRAN paging can be seen at TS 3GPP TS 25.211 and 25.304. Specifically, the UE shall select a secondary common control physical channel SCCPCH from the ones listed in supplementary information part B (SIB) based on its IMSI as follows:

- "Index of selected SCCPCH" = $\text{IMSI} \bmod K$, where (capital) K is equal to the number of listed SCCPCHs which carry a PCH;
- Paging Occasion = $[(\text{IMSI} \div K) \bmod \text{DRX cycle length}] + n * \text{DRX cycle length} + \text{Frame Offset}$; where $n = 0, 1, 2, \dots$ as long as SFN is below its maximum value.

[0015] The actual page indicator within a paging occasion that the UE shall read is similarly determined based on IMSI. The PI to use is calculated by using the following formula: $\text{PI} = [\text{DRX Index}] \bmod N_p$; where $\text{DRX Index} = \text{IMSI} \div 8192$. In the frequency division duplex FDD mode, $N_p = (18, 36, 72, 144)$ is the number of PIs per frame, and is given in the information element IE "Number of PI per frame" portion of the system information in FDD mode.

[0016] Due to the flexibility of the LTE deployable system bandwidth (i.e., ranging from 1.25MHz to 20MHz), there can be some capacity and delay issues affecting paging in the case of the narrower system bandwidths (e.g., 1.25MHz). For example, this can result in a given TTI (of 1 ms) having multiple other messages, for example a BCH that needs to be sent in that same TTI. A situation arises where there may not be sufficient radio resources for those other message and for paging in that single TTI, and so the paging may need to be postponed to the UE's next paging occasion/DRX duty cycle. There is also the need to enhance the probability of proper reception of paging messages. These teachings variously address both concerns.

SUMMARY:

[0017] In accordance with one exemplary aspect of the invention there is a method that includes designating a plural number m of time intervals of a k^{th} frame during which a user equipment is to monitor for a page; setting a parameter that specifies a set of the time intervals of the k^{th} frame, wherein a number of time intervals in the set comprises a number of time intervals equal to the plural number m ; and placing a page for the user equipment within at least one of the time intervals of the set of time intervals of the k^{th} frame.

[0018] In accordance with another exemplary aspect of the invention there is a memory storing a program of machine readable instructions executable by a processor for performing actions

that include designating a plural number m of time intervals of a k^{th} frame during which a user equipment is to monitor for a page; setting a parameter that specifies a set of the time intervals of the k^{th} frame, wherein a number of time intervals in the set comprises a number of time intervals equal to the plural number m ; and placing a page for the user equipment within at least one of the time intervals of the set of time intervals of the k^{th} frame.

[0019] In accordance with yet another exemplary aspect of the invention there is an apparatus that includes a processor that is configured to designate a plural number m of time intervals of a k^{th} frame during which a user equipment is to monitor for a page, to set a parameter that specifies a set of the time intervals of the k^{th} frame, wherein a number of time intervals in the set comprises a number of time intervals equal to the plural number m , and to place a page for the user equipment within at least one of the time intervals of the set of time intervals of the k^{th} frame.

[0020] In accordance with still another exemplary aspect of the invention there is an apparatus that includes processing means for designating a plural number m of time intervals of a k^{th} frame during which a user equipment is to monitor for a page, for setting a parameter that specifies a set of the time intervals of the k^{th} frame, wherein a number of time intervals in the set comprises a number of time intervals equal to the plural number m , and for placing a page for the user equipment within at least one of the time intervals of the set of time intervals of the k^{th} frame.

[0021] In accordance with a further exemplary aspect of the invention there is a method that includes determining a k^{th} frame in which to monitor for a page; determining from a parameter wirelessly received from a network a specified set of time intervals of the k^{th} frame during which to monitor for a page, in which there are a plural number m of time intervals in the set; and monitoring the set of time intervals until at least one of: a page is successfully received; or all of the plural number m of time intervals in the set have been monitored for the page.

[0022] In accordance with a still further exemplary aspect of the invention there is a memory storing a program of machine readable instructions executable by a processor for performing actions that include determining a k^{th} frame in which to monitor for a page, determining from a parameter wirelessly received from a network a specified set of time intervals of the k^{th} frame during which to monitor for a page, in which there are a plural number m of time intervals in the

set, and monitoring the set of time intervals until at least one of: a page is successfully received; or all of the plural number m of time intervals in the set have been monitored for the page.

[0023] In accordance with yet a still further exemplary aspect of the invention there is an apparatus that includes a processor which is configured to determine a k^{th} frame in which to monitor for a page, to determine from a parameter wirelessly received from a network a specified set of time intervals of the k^{th} frame during which to monitor for a page, in which there are a plural number m of time intervals in the set, and to tune a receiver to monitor the set of time intervals until at least one of: a page is successfully received; or all of the plural number m of time intervals in the set have been monitored for the page.

[0024] In accordance with still a further exemplary aspect of the invention there is an apparatus comprising processing means for determining a k^{th} frame in which to monitor for a page; for determining from a parameter wirelessly received from a network a specified set of time intervals of the k^{th} frame during which to monitor for a page, in which there are a plural number m of time intervals in the set; and for monitoring the set of time intervals until at least one of: a page is successfully received; or all of the plural number m of time intervals in the set have been monitored for the page.

BRIEF DESCRIPTION OF THE DRAWINGS:

[0025] The foregoing and other aspects of these teachings are made more evident in the following Detailed Description, when read in conjunction with the attached Drawing Figures.

[0026] Figure 1 is a prior art schematic diagram of the DRX concept in E-UTRAN.

[0027] Figure 2 is a table illustrating three embodiments of paging repeat/split according to aspects of the invention.

[0028] Figures 3A-B show simplified block diagrams of various electronic devices that are suitable for use in practicing the exemplary embodiments of this invention.

[0029] Figure 4 is a process flow diagram showing steps according to an embodiment of the invention for both the network and the user equipment.

DETAILED DESCRIPTION:

[0030] Embodiments of this invention relate to using multiple TTIs for paging a UE within some pre-designated number of system frames. This gives the network more flexibility to arrange those paging messages that the network sends, and that flexibility enables the network to avoid having to postpone sending a PI/page to a particular UE under heavy traffic and/or low bandwidth conditions. This results in technical advantages such as (a) improving correct reception of paging; (b) avoiding long paging delays; and (c) enhancing contention resolution on a random access channel (RACH) when multiple UE's pages in the same system frame attempt to access the system in response to paging causes. For example, advantage (a) above can be realized by the user equipment UE soft combining the same page received either in different TTIs of the same frame or the same page received in different frames so as to increase the received signal energy. This improves the time diversity gain which may be most beneficial e.g. in deep fade cases. In LTE the eNB may also allocate to a relay node certain of its radio resources for allocation by the relay to UEs under its own control autonomously, and so teachings herein relevant to the eNB also apply equally to relays that autonomously allocate radio resources to their UEs. The following detailed description is in the context of E-UTRAN/LTE, but this example is not limiting to the broader aspects of the invention.

[0031] Assume for example that the paging message which is used to page only one UE is fitted for transmission in one TTI, regardless of the system bandwidth currently deployed in the cell. According to an embodiment of the invention, the network specifies several TTIs within the same system frame of a paging occasion (e.g., within the paging and DRX rules) for which a UE (or group of UEs if paging groups are in use) will have its paging occasion. A convenient way to specify this uses system frame number SFN. According to one implementation, the network may specify it as: $\text{IMSI mod DRX cycle length} = \text{SFN mod DRX cycle length}$. The network then repeats the paging record of the UE in the paging messages in those several TTIs, specific to a given UE or UE group defined by the DRX rules (where UE groups are used), within the same system frame if the PAGING message is fitted in one TTI.

[0032] Consider an example: the network specifies the first and sixth TTI of a system frame (at a paging occasion) for transmitting paging and a given UE is to be paged by the network in $\text{SFN}=k$, where lowercase k is an index representing the SFN. The paging message for that UE will then be sent in the first TTI of $\text{SFN}=k$, and then repeated in the sixth TTI of $\text{SFN}=k$. This is shown at Figure 2: case 1. System frame number is given across the top of the timeline as 0, 1,

2, 3.

[0033] According to E-UTRAN TS 36.300 and TS 36.211, an LTE system frame is of duration 10 msec and has ten TTIs, each of 1 ms duration. Each TTI in a SFN can be used to carry e.g. PICH and PCH equivalents. Thus, the index k can be up to ten for a E-UTRAN implementation.

[0034] Each system frame in Figure 2 has ten blocks, each representing one TTI (for example, in an E-UTRAN frame). The UE has a paging occasion at SFN=0, so the network sends a paging indication to the UE within system frame number 0. Assume as is consistent with E-UTRAN that the network sends the paging within the first few OFDM symbols of the first TTI of system frame number zero. Then according to this example, the network sends the page for that UE, corresponding to that paging indication, in that first TTI as is normal for E-UTRAN, and also re-sends that same page in the sixth TTI of that same SNF=0. This is a repeat period of five; the page is sent initially in the first TTI of the SFN corresponding to the paging occasion, and the same page is repeated after five TTIs following the one in which the page was initially sent. The right side of Figure 2 repeats the same example for the next paging occasion of the first UE, and in this example there are no paging occasions for that UE other than in SFN=0 frames. The UE may receive and decode the two paging messages separately or use soft combining to jointly decode them in order to exploit a diversity gain, since in this example the page in the sixth TTI is simply a retransmission of the page in the first TTI. The UE knows from the DRX rules and the previously-noted network indications that the UE is to look in the first and in the sixth TTI of a frame for its pages.

[0035] As an option that can be used in addition to the example given above or separately, the paging message can contain paging records for more than one UE, and those paging records can be combined or split. For example, consider that there are pages for UE1 and UE2, that both UE1 and UE2 have the same system frame number for their paging occasion, and there is a paging indicator for both of them (for example, both UE1 and UE2 are in the same paging group, or the network sends a PI to each of them within the same TTI). In one implementation both UE1 and UE2 are sent a paging message having paging records for both in the first TTI and in the sixth TTI (assuming the example above) that are designated by the network for page repeats. So in this implementation each of UE1 and UE2 gets their initial page in the first TTI and the re-transmission of that same page in the sixth TTI. Each may do soft combining for more accurate decoding.

[0036] In another implementation, neither UE is sent a paging record re-transmission and the pages to the different UEs are sent in the different TTIs specified by the network. So for example the paging record for UE1 is sent in a paging message of first TTI but not in the sixth, and the paging record for UE2 is sent in a paging message of the sixth TTI but not in the first. This gives the eNB scheduler a bit more flexibility to deploy its radio resources. If there is still available downlink signaling resources, the network may still repeat one or both of those paging records within other paging messages of the frame, either in a specified TTI (first or sixth for example) or at random, but this is an option that the eNB may exercise on a frame by frame basis depending upon how crowded the frame is with other signaling and data.

[0037] Upon seeing its PI in the first few OFDM symbols of the first TTI of SFN=k, neither UE1 nor UE2 knows whether its page will be sent in the first or in the sixth TTI of that frame, but each monitors both TTIs since those are the two designated by the network. For the case where the network may send a repeat paging record in any random TTI, the UE must know in advance that it must monitor the entire frame in which it receives a PI. Regardless, according to the paging and DRX rules as adapted by embodiments of this invention, each UE in a cell monitors at least two TTIs within a frame in which it receives a paging indication. The network is not committed to send and re-send a paging record in those two instances under the above split-paging option, but is given the flexibility to use either TTI for sending a paging record to a particular UE in a particular frame based on traffic conditions. It is assumed for this split-paging option that radio resource control RRC (e.g., the eNB in E-UTRAN) knows how many UEs can be paged in one TTI, the RRC does the paging split into the several TTIs within the same frame, and the RRC generates the paging messages accordingly.

[0038] Of course, the paging repeat/split need not be a binary implementation with one re-transmission per frame per UE or split two UE pages among two TTIs of the frame. As a more generic implementation, the network may be enabled to send or split the paging in the same SFN by m times. In this example, the parameter K as currently defined in 3GPP TS 25.211 and 25.304 (see the background section above) can be set equal to the flooring operation $\lfloor 10/m \rfloor$, i.e., an integer not exceeding the argument $10/m$ and $1 \leq m \leq 10$. The parameter m can be UE specific or common to all UEs and indicated by the network such as via a message given to the UE upon entry into the cell (e.g., during handover or cell selection/reselection procedures for a UE-specific implementation) or sent via system information (for an implementation where m is

common to all UEs in the cell).

[0039] The m TTIs may be flexibly arranged within a SFN for each specified UE or UE group having the same paging occasion frame (e.g., $\text{IMSI mod } K$). For examples, m TTIs can be arranged as consecutive TTIs or discrete TTIs. Consecutive TTIs for paging repeats/splits is shown at case 2 of Figure 2. In this instance the network has designated the first and second TTI of the paging occasion frame as those TTIs in which a UE is to monitor for its page (if it receives a PI in the first few OFDM symbols of the first TTI of that frame). As with case 1, no additional paging occasions are available for that UE other than $\text{SFN}=0$, so giving the network the additional flexibility to send a page in either (or both) of the first or second TTI avoids the network having to postpone sending the PI and page to that UE until the next $\text{SFN}=0$ when the network is experiencing high traffic.

[0040] As noted above, the paged UE monitors the network-designated TTIs of the paging-occasion SFN one-by-one until finding its paging record. As an alternative such as where the network is enabled to send a repeat paging record randomly in the frame wherever it has room, the UEs may be tasked to monitor all the TTIs in the frame after receiving their PI. The number of TTIs is flexible and can be adjusted dynamically by the network, such as via the parameters m noted above. The specific arrangement of these TTI within the same system frame of a paging occasion, specified for a UE or a group of UEs having the same paging occasion in SFN, is also flexible.

[0041] So long as the network has the option of changing the number of TTIs, the repeat/split number may be zero in which case there is no repeat or split and there is only one TTI in a frame in which the network may place a paging record for a UE given a PI in that paging occasion frame. The paging related signaling is then similar to the prior art for E-UTRAN, the difference being that before any paging or PI is sent the network informs the UE that the repeat/split period is zero. This is shown at case 3 of Figure 2; the repeat period is zero and so the initial paging record is sent in the first TTI, the same TTI in which the PI is sent. But since the repeat is zero the UE need not monitor any further TTIs in that frame and the network does not send a repeat of the paging record elsewhere in the frame.

[0042] With respect to power consumption considerations within the UE, the simple implementation of m consecutive TTIs in the frame yields better UE power consumption figures,

where the paging is repeated or split in consecutive TTIs (it makes little difference to the UE power profile if the network decides in a particular instance to re-transmit or split the pages as the UE must monitor both; though slightly more power is used if the UE soft-combines the initial and re-transmitted page). The drawback to this lower-power UE approach is there may be an occasional deep fade in a radio channel which would be expected also to impact all those consecutive TTIs. In this regard, the discrete (non-consecutive) arrangement of those TTIs may offer a better gain. The dynamic flexibility detailed above enables the eNB to adjust to such deep fade scenarios as they are encountered, so as to offer the best multi-TTI paging occasions for the channel conditions that exist at any given time.

[0043] In UTRAN at least, more than one PI may be sent in a single TTI as noted above in the background section. This is configurable for UTRAN as $N_p = (18, 36, 72, 144)$ PIs that can be sent in a TTI equal to a system frame of 10ms at a paging occasion. So for example (1, 2, 4, 8) PIs per 1ms TTI could be set for LTE E-UTRAN. According to specific embodiments of these teachings, each of these (1, 2, 4, 8) PIs would then potentially have an associated paging record in another TTI of that same system frame, and each of the UEs to which the paging indication is directed monitors m TTIs within the frame for its paging record, as indicated by the network (individually or via broadcast across the whole cell) and disposed throughout the frame according to the algorithm (e.g., as noted above based on IMSI) known to both the network and the UE. Depending on whether the network chooses to repeat or split the paging records for those 1, 2, 4 or 8 UEs to which the PIs are directed, individual ones of those 1, 2, 4 or 8 UEs may see their paging record as few as once in the frame (in the first TTI) or as many as m times in the frame.

[0044] Note also that it is possible for an individual UE to see its paging record any number of times between one and m times within a frame, as the network may choose in one instance to repeat/re-transmit the paging record over some of the m pre-determined TTIs and may choose in another instance to split it with pages to other UEs for other of the m pre-determined TTIs. For the case where m is greater than two, the network may elect both options simultaneously: retransmit the same page to a first UE in multiple ones but less than all of the designated m TTIs, and in the remaining TTI or TTIs of the designated m TTIs the network sends a page to another UE but not to the first UE. Thus while repeating the page is one option for the network and splitting the page is another option, the two are not mutually exclusive if m is greater than two. This represents the network's flexibility, and the UE is obligated always to monitor all of the

m TTIs unless/until it successfully receives its paging record prior to the last of the m TTIs. This is illustrated by example. Assume $m=3$, which for a particular UE represents the first, fourth and ninth TTIs of the frame in which it has a paging occasion. The UE sees its PI within the first few OFDM symbols of the first TTI of that frame, and when monitoring the first TTI does not see its paging record. It then monitors the fourth TTI and again does not see its paging record. It is obliged to continue monitoring in the ninth TTI, where it finally sees its paging record. The network may have split the paging records for different UEs and sent the record for this particular UE only in the ninth TTI of the frame.

[0045] Assuming the same scenario where $m=3$ represents for a particular UE the first, fourth and ninth TTIs of the frame, now consider that the UE again fails to see its paging record in the first TTI but does see it in the fourth TTI of the frame. The network can send a repeat of that same page in the ninth TTI since in this instance the first, fourth and ninth TTI are designated. Assuming there was only one PI for that same UE in the first TTI, then in an embodiment the UE need not monitor the ninth TTI of the frame since it already has received its page associated with that PI. This is despite the fact that $m=3$ informs this UE that its paging message may be in the first, fourth or ninth TTI of the paging occasion frame. The UE may choose to monitor that ninth TTI anyway for diversity gain and joint detection/soft decoding, but it knows in advance that since there was only one PI in the frame there will be in substance only one paging record for it in the frame. Any paging record the UE might receive in the ninth TTI will necessarily be a repeat of what it already received in the fourth TTI since only one PI was sent in the frame. This option for the UE to discontinue monitoring remaining ones of the m designated frames once it receives its paging record is seen to recapture some of the additional power demand placed upon it by giving the network the flexibility to send the paging record in any or all of m TTIs of the frame in which the UE has a paging occasion.

[0046] If in fact the UE continues to monitor and sees a repeat of its paging record in the ninth TTI, the UE can soft combine these paging records from the fourth and ninth TTI to increase signal strength and reception quality. A UE with good signal coverage can receive the paging record correctly from only the fourth TTI, whereas if the UE were at the edge of the cell and in poor coverage conditions it might need both the fourth and ninth TTI paging records to yield a correct reception. Whether a UE continues to monitor for its page in additional ones of the designated TTIs after receiving a first page in a designated one of the m TTIs which is not the final m th TTI may therefore be predicated on signal quality. For example, the UE may have the

flexibility to decide whether or not it should monitor for a second instance of its paging record based on its signal quality or whether its first decoding attempt using only one received page is within decoding error limits, or the network may choose to send a repeat of a page to those UEs that report weak signal strength in their channel measurement reports. There may be a prearranged threshold, such as published in a wireless standard or broadcast in the cell by the network (e.g., system information). The UE reports channel quality as already contemplated in E-UTRAN (or in other wireless standards) for various other purposes. The network compares the received channel quality against the threshold and the UE compares the channel quality that it reports against the threshold. If the channel quality does not exceed the prearranged threshold based on the comparison, the network will send a repeat page and the UE will monitor for a repeat page. If the channel quality does exceed the threshold in the comparison, then the network may repeat the page and/or the UE may continue to monitor additional ones of the predetermined m TTIs after receiving a first page, as either entity sees fit (but neither would be compelled to do so by the wireless standard).

[0047] Embodiments of this invention therefore yield certain technical advantages. The correct-reception probability of paging records/messages is improved with insignificant delay (i.e., within a SFN of 10ms for E-UTRAN, but in any case without postponing the PI to the next frame in which the UE has a paging occasion). Also, splitting multiple UEs, eventually paged in the same SFN of a paging occasion, into several TTIs helps in contention resolution of RACH when the paged UEs attempt to access on the RACH in response to receiving their paging records. This is because it is more likely with embodiments of this invention that there will only be a single UE having its page record in a particular TTI, so the likelihood of multiple UEs transmitting on the RACH is less as compared to the case where multiple UEs receive their paging record in the same TTI. Additionally, having multiple TTIs for paging a UE within one system frame gives network more flexibility to arrange the paging messages that it needs to send, and helps avoid long paging delays since the probability for postponing a paging to next DRX cycle/paging occasion is decreased.

[0048] Increased power consumption within the UE is a concern, but as noted above are mitigated in that once a UE receives its paging message, in certain embodiments it no longer needs to monitor remaining ones of the m designated TTIs in the frame, at least where signal strength of the page received in the first instance exceed a threshold signal strength or other signal quality level. So for all instances in which the prior art E-UTRAN paging arrangement

would NOT postpone paging to the next DRX period/paging occasion, the pages may be sent in the first TTI and power consumption within the UE need not be increased. But for those instances where the prior art paging protocol would postpone sending the PI and associated page to the next paging occasion, the tradeoff is slightly higher power consumption at the UE versus postponing its PI and page. In most instances this is a technical advantage because it is anticipated that the higher power consumption would be preferable to the delayed page. For those instances where the prior art single page would be too weak to be correctly received at the UE, the repeat page according to these teachings yields no increased power consumption and the technical advantage is that the network gets the correctly received page to the UE faster than the prior art regimen, which would necessarily have to re-transmit a new PI and a new page after the first one was not correctly received.

[0049] The above description presumed for simplicity that the designated TTIs are confined to only one system frame index number, but this is not a limitation to these teachings. For example, further advantages for the soft-combining aspect may be obtained by spreading the initial paging record and the repeat of that initial paging record over multiple frames so as to better exploit time diversity for the UE's soft combining of the paging records. In an embodiment, the default condition is that the m designated frames are confined to a single frame and further network signaling informs the UE that its page may be found in one or more corresponding (same index) TTIs of other frames (other SFN frame indices). This may be a single bit from the network that tells the UE to monitor a subsequent frame. In one embodiment the single bit indicator tells the UE to monitor the next consecutive frame, in which the UE then monitors the first TTI of that next subsequent frame and also the other designated TTIs of the next subsequent frame. In another embodiment that single bit tells the UE to monitor designated TTIs that are determined by an algorithm analogous to that used to determine the designated TTIs, whether the same or different algorithm. So in an example, if the $m=3$ TTIs are the first, fourth and ninth TTIs of a frame as above, the additional bit may be set to instruct the UE to also monitor those same designated TTIs of the first system frame, the fourth system frame and the ninth system frame. Alternatively, the multi-frame monitoring of those additional subsequent frames may be understood by the UE and the network to instruct the UE to monitor only one TTI of those further system frames beyond the first system frame, such as always the first TTI of the designated frames beyond the first frame, or always only the second-designated TTI of those further system frames beyond the first system frame.

[0050] These various exemplary and non-limiting embodiments are shown in tabular format below for the example $m=3$ designated the first, fourth and ninth TTI of the first frame. Blank entries in the table mean there are no TTIs in the frame during which the UE will monitor, or the network will send, a page associated with the PI sent in the first TTI (e.g., first few OFDM symbols of that TTI) of the first frame. As can be seen, a single bit indication for multi-TTI monitoring can be understood to mean many things so long as both network and UE have the same conception how to interpret that bit. It may be prudent that they understand it to mean other than the first TTI in those frames subsequent to the first frame since the network will generally try to place other paging indicators and their related pages for other UEs in that first TTI, and would generally have wider flexibility for placing repeat pages in other than the first TTI of any frame. Of course, more than a single bit may be used to indicate which further frames and which TTIs of those further frames are to be monitored for the UE's page. Note in the last row entry that the designated TTIs are spread across their companion frame numbers. A slight variation on this does not have to match TTI index to frame index, though some additional signaling would be required to properly map TTI index to frame index in a flexible manner.

[0051] Repeat/Split Opportunities Across Multi-Frames for Page(s) Associated With One PI:

<u>First frame</u>	<u>Second frame</u>	<u>Fourth frame</u>	<u>Ninth frame</u>
1 st , 4 th and 9 th TTI	1 st TTI		
1 st , 4 th and 9 th TTI	1 st , 4 th and 9 th TTI		
1 st , 4 th and 9 th TTI		1 st TTI	
1 st , 4 th and 9 th TTI		1 st TTI	1 st TTI
1 st , 4 th and 9 th TTI	4 th TTI		
1 st , 4 th and 9 th TTI		4 th TTI	
1 st , 4 th and 9 th TTI		4 th TTI	9 th TTI
1 st TTI		4 th TTI	9 th TTI

[0052] Reference is now made to Figure 3A for illustrating a simplified block diagram of various electronic devices that are suitable for use in practicing the exemplary embodiments of this invention, and to Figure 3B which illustrates in plan and sectional views further detail of an exemplary UE 10. In Figure 3A a wireless network 8 is adapted for communication between a UE 10 and a Node B 12 (e-Node B). The network 8 may include a gateway GW/serving mobility management entity MME/radio network controller RNC 14 or other radio controller function known by various terms in different wireless communication systems. The UE 10 includes a

data processor (DP) 10A, a memory (MEM) 10B that stores a program (PROG) 10C, and one or more suitable radio frequency (RF) transceivers 10D (combination transmitter and receiver, one shown) coupled to one or more antennas for bidirectional wireless communications over one or more wireless links 11 with the Node B 12.

[0053] The terms "connected," "coupled," or any variant thereof, mean any connection or coupling, either direct or indirect, between two or more elements, and may encompass the presence of one or more intermediate elements between two elements that are "connected" or "coupled" together. The coupling or connection between the elements can be physical, logical, or a combination thereof. As employed herein two elements may be considered to be "connected" or "coupled" together by the use of one or more wires, cables and printed electrical connections, as well as by the use of electromagnetic energy, such as electromagnetic energy having wavelengths in the radio frequency region, the microwave region and the optical (both visible and invisible) region, as non-limiting examples.

[0054] The Node B 12 also includes a DP 12A, a MEM 12B, that stores a PROG 12C, and one or more suitable RF transceivers 12D (one shown) coupled to one or more antennas 12E (one shown, typically an array). The Node B 12 may be coupled via a data path 13 (e.g., Iub or S1 interface) to the serving or other GW/MME/RNC 14. The GW/MME/RNC 14 includes a DP 14A, a MEM 14B that stores a PROG 14C, and a suitable modem and/or transceiver (not shown) for communication with the Node B 12 over the S1 link 13.

[0055] Also within the node B 12 is a traffic scheduler 12F that schedule the various UEs under its control for the various UL and DL traffic subframes which are allocated by the PDCCH, and a page scheduler function or unit 12G which schedules the various PIs and pages within the various TTIs of the frame for different ones of the UEs in the cell as detailed above. The page scheduler 12G may be combined with the traffic scheduler 12F and both may be combined into the DP 12A in certain embodiments. Generally, the Node B 12 of an LTE system is fairly autonomous in its scheduling and need not coordinate with the GW/MME 14 excepting during handover of one of its UEs to another Node B. For the purposes of describing the exemplary embodiments of this invention the UE 10 may be assumed to also include a page schedule tracking function or unit 10G which in some embodiments may be performed or embodied by the DP 10A. The UE's page schedule tracker function or unit 10G works in conjunction with the page scheduler 12G of the Node B 12 for coordinated implementation of UE-centric and

network-centric embodiments of the invention across both sides of the wireless link 11.

[0056] At least one of the PROGs 10C, 12C and 14C is assumed to include program instructions that, when executed by the associated DP, enable the electronic device to operate in accordance with the exemplary embodiments of this invention, as detailed above. Inherent in the DPs 10A, 12A, and 214A is a clock to enable synchronism among the various apparatus for transmissions and receptions within the appropriate time intervals and slots and frames required, as these timing partitions of the radio spectrum are time dependent.

[0057] The PROGs 10C, 12C, 14C may be embodied in software, firmware and/or hardware, as is appropriate. In general, the exemplary embodiments of this invention may be implemented by computer software stored in the MEM 10B and executable by the DP 10A of the UE 10 and similar for the other MEM 12B and DP 12A of the Node B 12, or by hardware, or by a combination of software and/or firmware and hardware in any or all of the devices shown.

[0058] In general, the various embodiments of the UE 10 can include, but are not limited to, mobile stations, cellular telephones, personal digital assistants (PDAs) having wireless communication capabilities, portable computers having wireless communication capabilities, image capture devices such as digital cameras having wireless communication capabilities, gaming devices having wireless communication capabilities, music storage and playback appliances having wireless communication capabilities, Internet appliances permitting wireless Internet access and browsing, as well as portable units or terminals that incorporate combinations of such functions.

[0059] The MEMs 10B, 12B and 14B may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor-based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The DPs 10A, 12A and 14A may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on a multi-core processor architecture, as non-limiting examples.

[0060] For the aspects of this invention related to the network, embodiments of this invention

may be implemented by computer software executable by a data processor of the Node B 12, such as the processor 12A shown, or by hardware, or by a combination of software and hardware. For the aspects of this invention related to the UE 10, embodiments of this invention may be implemented by computer software executable by a data processor of the UE 10, such as the processor 10A shown, or by hardware, or by a combination of software and hardware. Further in this regard it should be noted that the various logical step descriptions above and below may represent program steps, or interconnected logic circuits, blocks and functions, or a combination of program steps and logic circuits, blocks and functions.

[0061] Figure 3B illustrates further detail of an exemplary UE in both plan view (left) and sectional view (right), and the invention may be embodied in one or some combination of those more function-specific components. At Figure 3B the UE 10 has a graphical display interface 20 and a user interface 22 illustrated as a keypad but understood as also encompassing touch-screen technology at the graphical display interface 20 and voice-recognition technology received at the microphone 24. A power actuator 26 controls the device being turned on and off by the user. The exemplary UE 10 may have a camera 28 which is shown as being forward facing (e.g., for video calls) but may alternatively or additionally be rearward facing (e.g., for capturing images and video for local storage). The camera 28 is controlled by a shutter actuator 30 and optionally by a zoom actuator 30 which may alternatively function as a volume adjustment for the speaker(s) 34 when the camera 28 is not in an active mode.

[0062] Within the sectional view of Fig. 3B are seen multiple transmit/receive antennas 36 that are typically used for cellular communication. The antennas 36 may be multi-band for use with other radios in the UE. The operable ground plane for the antennas 36 is shown by shading as spanning the entire space enclosed by the UE housing though in some embodiments the ground plane may be limited to a smaller area, such as disposed on a printed wiring board on which the power chip 38 is formed. The power chip 38 controls power amplification on the channels being transmitted and/or across the antennas that transmit simultaneously where spatial diversity is used, and amplifies the received signals. The power chip 38 outputs the amplified received signal to the radio-frequency (RF) chip 40 which demodulates and downconverts the signal for baseband processing. The baseband (BB) chip 42 detects the signal which is then converted to a bit-stream and finally decoded. Similar processing occurs in reverse for signals generated in the apparatus 10 and transmitted from it.

[0063] Signals to and from the camera 28 pass through an image/video processor 44 which encodes and decodes the various image frames. A separate audio processor 46 may also be present controlling signals to and from the speakers 34 and the microphone 24. The graphical display interface 20 is refreshed from a frame memory 48 as controlled by a user interface chip 50 which may process signals to and from the display interface 20 and/or additionally process user inputs from the keypad 22 and elsewhere.

[0064] Certain embodiments of the UE 10 may also include one or more secondary radios such as a wireless local area network radio WLAN 37 and a Bluetooth® radio 39, which may incorporate an antenna on-chip or be coupled to an off-chip antenna. Throughout the apparatus are various memories such as random access memory RAM 43, read only memory ROM 45, and in some embodiments removable memory such as the illustrated memory card 47 on which the various programs 10C are stored. All of these components within the UE 10 are normally powered by a portable power supply such as a battery 49.

[0065] The aforeseaid processors 38, 40, 42, 44, 46, 50, if embodied as separate entities in a UE 10 or eNB 12, may operate in a slave relationship to the main processor 10A, 12A, which may then be in a master relationship to them. Embodiments of this invention may implement the page schedule tracker function 10G within the baseband processor 42 though it is noted that other embodiments need not disposed the tracker function 10G there but instead may implement it across multiple ones of the various chips and memories as shown or within another processor that combines some subset of the different functions described above for Figure 3B. Any or all of these various processors of Fig. 3B access one or more of the various memories, which may be on-chip with the processor or separate therefrom. Similar function-specific components that are directed toward communications over a network broader than a piconet (e.g., components 36, 38, 40, 42-45 and 47) may also be disposed in exemplary embodiments of the access node 12, which may have an array of tower-mounted antennas rather than the two shown at Fig. 3B.

[0066] Note that the various chips (e.g., 38, 40, 42, etc.) that were described above may be combined into a fewer number than described and, in a most compact case, may all be embodied physically within a single chip. The page schedule tracker function 10G may be implemented in any of these alternative hardware implementations.

[0067] Figure 4 is a process flow diagram outlining steps in accordance with an embodiment of the invention as detailed further above. At block 400 the network transmits, and the UE receives, an indicator (termed a first indicator, to distinguish over the paging indicator) of how many designated time intervals or slots a paging message may be sent. The first indicator may be a parameter such as m noted above by example, by which the network and the UE know both how many TTIs or slots in a frame are designated for paging that UE, but also which of the TTIs or slots within that frame. This is done for example by executing an algorithm stored in the local memory of the UE and of the network that is a function of the parameter m and of the IMSI of the UE or of the RNTI (e.g., C-RNTI or P-RNTI) of the UE or its paging group. The parameter m may be signaled by the network to the UE in a point to point message, such as during cell selection/reselection procedures when the UE first becomes established in the network's cell, or the network may broadcast the parameter m via system information or in some other broadcast message to all UEs within the cell. At block 402, the network sends and the UE receives a paging indicator directed to the UE within a frame in which the UE is scheduled for a paging occasion. This paging indicator may be directed to the specific UE individually or to a paging group in which the UE is a member. The network sends at block 404 a paging record to the UE within the frame and within at least one of the designated time intervals. Automatically responsive to receiving the paging indication at block 402, the UE monitors at block 406 the designated time intervals or slots one by one until at least the UE receives a paging record sent from the network. If there is no paging for any UE having a paging occasion at this point in time, no paging record will be sent at block 404, and neither will the PI (P-RNTI) be sent at block 402 so the UE will not be monitoring the slots at block 406. At block 408 the UE contacts the network in response to receiving its page, which as shown in Figure 4 is via a random access channel RACH.

[0068] As can be appreciated, the aspects of the invention as described generally at Figure 4 and the related text may be embodied in an apparatus such as the UE 10 or the node B 12, or in a memory tangibly embodying a computer readable program that causes a processor to perform those steps and other more detailed implementations that are described above, or it may be embodied as a method for the separate UE and network element, or it may be embodied as an integrated circuit wherein the various process blocks of Figure 4 represent functional circuitry of the respective UE/network node as the case may be.

[0069] According to an aspect of the invention, there is an apparatus such as a network

element (e.g., a base station/node B), a computer readable memory embodying a program executable by a processor, and a method that operates to transmit a first indicator of how many designated time intervals (e.g., slots in a frame) in one or more designated frames a page may be sent, to send a paging indication to a user equipment within a time interval of a frame in which the user equipment is scheduled for a paging occasion, and to send a page to the user equipment within at least one of the designated time intervals of one of the designated frames. The first indicator (e.g., parameter m) may indicate the number of time intervals and also which time intervals of the designated frames a paging message may be sent (e.g., by executing an algorithm stored in the local memory that is a function of the parameter m and of the IMSI or temporary identifier of the user equipment or a paging group in which the user equipment is a member), where in this embodiment by default the one frame is the frame in which the paging indication is sent. The first indicator may be sent to the user equipment in a point to point message (e.g., during cell selection/reselection procedures) or it may be broadcast (e.g., system information) in the cell. The paging indication may be directed to the specific user equipment individually, or to a paging group in which the user equipment is a member. The page may be sent in one or in any multiple ones of the designated time intervals of the designated frame or frames. Thereafter, a message may be received from the user equipment seeking access to the network on a random access or other shared channel. A second indicator may be sent that designates the frames if the time intervals are spread across multiple frames, or the spread may be pre-arranged (e.g., a time interval index corresponds to a frame number index). In an embodiment, the network may send a second indication that the page may be sent one or more subsequent frames, and the second indication will be prearranged to designate one or more specific time intervals in one or more specific frames by which the page, or a repeat of the page, may be sent.

[0070] According to another aspect of the invention, there is an apparatus such as a user equipment (e.g., a mobile terminal or other wireless device that is not an element of the network itself), a computer readable memory embodying a program executable by a processor, and a method that operates to receive from a network a first indicator of how many designated time intervals (e.g., slots) in one or more designated frames a page may be sent by the network to the user equipment, to receive a paging indication from the network within a time interval of a frame in which the user equipment is scheduled for a paging occasion, and then automatically responsive to receiving the paging indication to monitor the designated time intervals or slots one by one (e.g., sequentially and chronologically) of the designated frame or frames until

receiving a page from the network in at least one of the designated time intervals. Thereafter in this embodiment the user equipment contacts the network in response to receiving its page, such as by initiating contact over a random access or other shared channel. In an embodiment, by default all of the designated time intervals are within the frame in which the user equipment receives the paging indication. The first indicator (e.g., parameter m) may indicate the number of time intervals in a frame and also which time intervals of the frame that the user equipment is to monitor for a page from the network that is directed to the user equipment (e.g., by executing an algorithm stored in the local memory that is a function of the parameter m and of the IMSI or temporary identifier of the user equipment or a paging group in which the user equipment is a member). The first indicator may be received by the user equipment in a point to point message (e.g., during cell selection/reselection) or it may be received over a broadcast channel (e.g., as system information) in the cell. The paging indication may be directed to the specific user equipment individually, or to a paging group in which the individual user equipment is a member. The page may be received by the user equipment in one or in any multiple ones of the designated time intervals, which may be within one frame if the designated frame is only one or spread across multiple frames if there are multiple designated frames. In an embodiment, only after receiving the page in one of the designated time intervals of the frame may the user equipment terminate monitoring subsequent ones of the designated time intervals of the frame for its page. In another embodiment the user equipment may soft-combine and jointly decode multiple ones of the page received in multiple ones of the designated time intervals of the designated frame(s). The user equipment may receive a second indicator that designates the frames if the time intervals are spread across multiple frames, or the spread of the designated time intervals across the multiple frames may be pre-arranged (e.g., a time interval index corresponds to a frame number index). The user equipment then monitors for the page or for a repeat of the page one by one across the designated time intervals of the designated frames as noted above.

[0071] In general, the various embodiments may be implemented in hardware or special purpose circuits, software (computer readable instructions embodied on a computer readable medium), logic or any combination thereof. For example, some aspects may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device, although the invention is not limited thereto. While various aspects of the invention may be illustrated and described as block diagrams, flow charts, or using some other pictorial representation, it is well understood

that these blocks, apparatus, systems, techniques or methods described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

[0072] Embodiments of the inventions may be practiced in various components such as integrated circuit modules. The design of integrated circuits is by and large a highly automated process. Complex and powerful software tools are available for converting a logic level design into a semiconductor circuit design ready to be etched and formed on a semiconductor substrate.

[0073] Programs, such as those provided by Synopsys, Inc. of Mountain View, California and Cadence Design, of San Jose, California automatically route conductors and locate components on a semiconductor chip using well established rules of design as well as libraries of pre-stored design modules. Once the design for a semiconductor circuit has been completed, the resultant design, in a standardized electronic format (e.g., Opus, GDSII, or the like) may be transmitted to a semiconductor fabrication facility or "fab" for fabrication.

[0074] Various modifications and adaptations may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the accompanying drawings. However, any and all modifications of the teachings of this invention will still fall within the scope of the non-limiting embodiments of this invention. For example, while the exemplary embodiments have been described above in the context of the EUTRAN (UTRAN-LTE) system, it should be appreciated that the exemplary embodiments of this invention are not limited for use with only this one particular type of wireless communication system, and that they may be used to advantage in other wireless communication systems such as for example UTRAN, GSM, GERAN, etc. Further, the various names used for the described parameters (e.g., P-RNTI, DRX, TTI, frame, etc.) are not intended to be limiting in any respect, as these parameters may be identified by any suitable names. Further, the formulas and expressions that use these various parameters may differ from those expressly disclosed herein. Further, the various names assigned to different channels (e.g., PDCCH, PICH, PCH, RACH, etc.) are not intended to be limiting in any respect, as these various channels may be identified by any suitable names.

[0075] Although described in the context of particular embodiments, it will be apparent to those skilled in the art that a number of modifications and various changes to these teachings may occur. Thus, while the invention has been particularly shown and described with respect to one or more embodiments thereof, it will be understood by those skilled in the art that certain modifications or changes may be made therein without departing from the scope of the invention as set forth above.

CLAIMS:

We claim:

1. A method comprising:
designating a plural number m of time intervals of a k^{th} frame during which a user equipment is to monitor for a page;
setting a parameter that specifies a set of the time intervals of the k^{th} frame, wherein a number of time intervals in the set comprises a number of time intervals equal to the plural number m ; and
placing a page for the user equipment within at least one of the time intervals of the set of time intervals of the k^{th} frame.
2. The method of claim 1, wherein the parameter specifies the set of time intervals with reference to discontinuous reception rules for the user equipment.
3. The method of any one of claims 1 or 2, wherein the parameter specifies that the m time intervals of the k^{th} frame are consecutive time intervals.
4. The method of any one of claims 1 or 2, wherein the parameter comprises a repeat period that specifies spacing between time intervals of the set.
5. The method of any one of claims 1 or 2, executed by a network access node and wherein the time intervals comprise transmission time intervals and the frame spans ten transmission time intervals or an integer multiple thereof, the method further comprising:
sending to the user equipment a paging indication in the k^{th} frame and sending to the user equipment the page within at least one of the time intervals of the set of time intervals of the k^{th} frame.
6. The method of claim 5, wherein the network access node sends the page to the user equipment in each of the m transmission time intervals of the k^{th} frame.
7. The method of claim 5, wherein the paging indication is for a group of user equipments that includes the said user equipment which is a first user equipment and that also includes a

second user equipment;

wherein the network access node sends the page to the first user equipment in one of the transmission time intervals of the set of transmission time intervals of the k^{th} frame, and further sends a different page to the second user equipment in another one of the transmission time intervals of the set of transmission time intervals of the k^{th} frame

8. The method of any one of claims 1 or 2, executed by a network access node and further comprising transmitting the parameter which is a first indicator that indicates the plural number m .

9. The method of claim 8, the method further comprising the network access node designating at least one additional frame other than the k^{th} frame during which a user equipment is to monitor for a page and sending an indication of the additional frame to the user equipment;

wherein placing the page for the user equipment within at least one of the time intervals of the set of time intervals of the k^{th} frame comprises placing a re-transmission of the page for the user equipment in at least time interval of the additional frame which corresponds to a time interval of the set of time intervals of the k^{th} frame.

10. A memory storing a program of machine readable instructions executable by a processor for performing actions comprising:

designating a plural number m of time intervals of a k^{th} frame during which a user equipment is to monitor for a page;

setting a parameter that specifies a set of the time intervals of the k^{th} frame, wherein a number of time intervals in the set comprises a number of time intervals equal to the plural number m ; and

placing a page for the user equipment within at least one of the time intervals of the set of time intervals of the k^{th} frame.

11. The memory of claim 12, wherein the actions further comprise:

transmitting the parameter that indicates the plural number m ;

sending to the user equipment a paging indication in the k^{th} frame; and

sending to the user equipment and a page within the at least one of the time intervals of the set of time intervals of the k^{th} frame.

12. An apparatus comprising a processor configured to:
 - designate a plural number m of time intervals of a k^{th} frame during which a user equipment is to monitor for a page;
 - set a parameter that specifies a set of the time intervals of the k^{th} frame, wherein a number of time intervals in the set comprises a number of time intervals equal to the plural number m ; and
 - place a page for the user equipment within at least one of the time intervals of the set of time intervals of the k^{th} frame.
13. The apparatus of claim 12, wherein the parameter specifies the set of time intervals with reference to discontinuous reception rules for the user equipment.
14. The apparatus of any one of claims 12 or 13, wherein the parameter specifies that the m time intervals of the k^{th} frame are consecutive time intervals.
15. The apparatus of any one of claims 12 or 13, wherein the parameter comprises a repeat period that specifies spacing between time intervals of the set.
16. The apparatus of any one of claims 12 or 13, wherein the apparatus comprises a network access node and wherein the time intervals comprise transmission time intervals and the frame spans ten transmission time intervals or an integer multiple thereof, the apparatus further comprising:
 - a transmitter configured to send to the user equipment a paging indication in the k^{th} frame and to send to the user equipment the page within at least one of the time intervals of the set of time intervals of the k^{th} frame.
17. The apparatus of claim 16, wherein the transmitter is configured to send the page to the user equipment in each of the m transmission time intervals of the k^{th} frame.
18. The apparatus of claim 16, wherein the paging indication is for a group of user equipments that includes the said user equipment which is a first user equipment and that also includes a second user equipment;
 - wherein the transmitter is configured to send the page to the first user equipment in one of the transmission time intervals of the set of transmission time intervals of the k^{th} frame, and is

configured to send a different page to the second user equipment in another one of the transmission time intervals of the set of transmission time intervals of the k^{th} frame

19. The apparatus of any one of claims 12 or 13, wherein the apparatus comprises a network access node which further comprises a transmitter configured to transmit the parameter which is a first indicator that indicates the plural number m .

20. The apparatus of claim 19, wherein the processor is further configured to designate at least one additional frame other than the k^{th} frame during which a user equipment is to monitor for a page and the transmitter is configured to send an indication of the additional frame to the user equipment;

wherein the transmitter is configured to send the page for the user equipment within at least one of the time intervals of the set of time intervals of the k^{th} frame and to re-transmit the page for the user equipment in at least time interval of the additional frame which corresponds to a time interval of the set of time intervals of the k^{th} frame.

21. An apparatus comprising processing means for:

designating a plural number m of time intervals of a k^{th} frame during which a user equipment is to monitor for a page;

setting a parameter that specifies a set of the time intervals of the k^{th} frame, wherein a number of time intervals in the set comprises a number of time intervals equal to the plural number m ; and

placing a page for the user equipment within at least one of the time intervals of the set of time intervals of the k^{th} frame.

22. A method comprising:

determining a k^{th} frame in which to monitor for a page;

determining from a parameter wirelessly received from a network a specified set of time intervals of the k^{th} frame during which to monitor for a page, in which there are a plural number m of time intervals in the set; and

monitoring the set of time intervals until at least one of: a page is successfully received; or all of the plural number m of time intervals in the set have been monitored for the page.

23. The method of claim 22, wherein the parameter specifies the set of time intervals with

reference to discontinuous reception rules for a user equipment to which the page is directed.

24. The method of claim 23, wherein the parameter specifies the set of time intervals with reference to discontinuous reception rules for the user equipment as:

$$\text{IMSI mod [DRX cycle length]} = \text{SFN mod [DRX cycle length]};$$

wherein IMSI comprises a unique identifier for the user equipment;

DRX cycle length comprises an indication of discontinuous reception period for the user equipment; and

SFN comprises a frame index that identifies the k^{th} frame.

25. The method of any one of claims 22, 23 or 24, in which the page is found in at least two of the plural number m of time intervals and soft combined by a user equipment executing the method.

26. The method of any one of claims 22, 23 or 24, wherein the parameter comprises a first indicator that indicates the plural number m ;

the method further comprising determining from a second parameter wirelessly received from the network at least one additional frame other than the k^{th} frame during which to monitor for the page;

wherein monitoring comprises monitoring the set of time intervals in the k^{th} frame and designated corresponding time intervals of the at least one additional frame until the at least one of: the page is successfully received; or all of the plural number m of time intervals in the set and the designated corresponding time intervals of the at least one additional frame have been monitored for the page.

27. A memory storing a program of machine readable instructions executable by a processor for performing actions comprising:

determining a k^{th} frame in which to monitor for a page;

determining from a parameter wirelessly received from a network a specified set of time intervals of the k^{th} frame during which to monitor for a page, in which there are a plural number m of time intervals in the set; and

monitoring the set of time intervals until at least one of: a page is successfully received; or all of the plural number m of time intervals in the set have been monitored for the page.

28. The memory of claim 27, in which the page is found in at least two of the plural number m of time intervals and the actions further comprise soft combining the received pages.
29. An apparatus comprising a processor configured to:
determine a k^{th} frame in which to monitor for a page;
determine from a parameter wirelessly received from a network a specified set of time intervals of the k^{th} frame during which to monitor for a page, in which there are a plural number m of time intervals in the set; and
tune a receiver to monitor the set of time intervals until at least one of: a page is successfully received; or all of the plural number m of time intervals in the set have been monitored for the page.
30. The apparatus of claim 29, wherein the parameter specifies the set of time intervals with reference to discontinuous reception rules for a user equipment to which the page is directed.
31. The apparatus of any one of claims 28 or 29, in which the page is found in at least two of the plural number m of time intervals and the processor is further configured to soft combine the found pages.
32. An apparatus comprising processing means for:
determining a k^{th} frame in which to monitor for a page;
determining from a parameter wirelessly received from a network a specified set of time intervals of the k^{th} frame during which to monitor for a page, in which there are a plural number m of time intervals in the set; and
monitoring the set of time intervals until at least one of: a page is successfully received; or all of the plural number m of time intervals in the set have been monitored for the page.
33. The apparatus of claim 32, wherein the processor is further configured to soft combine plural instances of the page found in different ones of the plural number m of time intervals.

PDCCH	PDCH	DRX	PDCCH	PDCH	DRX
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Figure 1: Prior Art

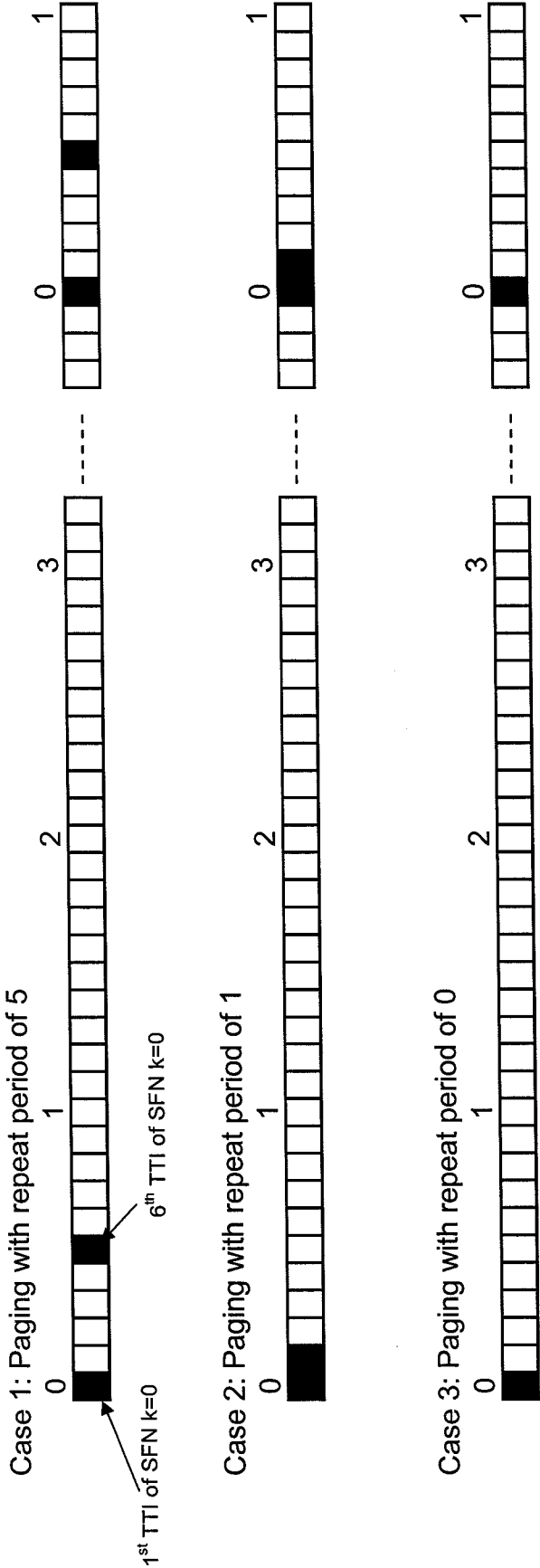


Figure 2

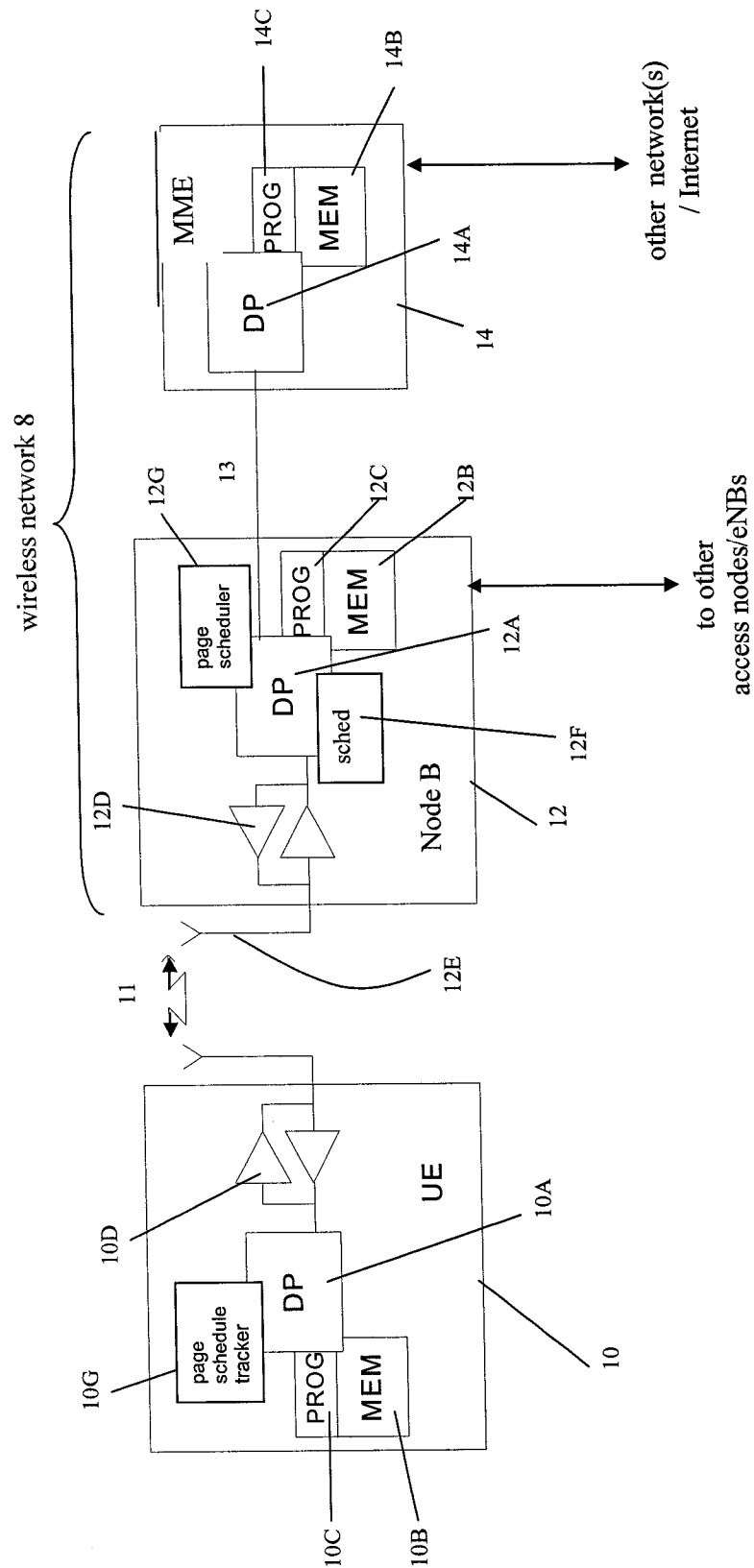


Figure 3A

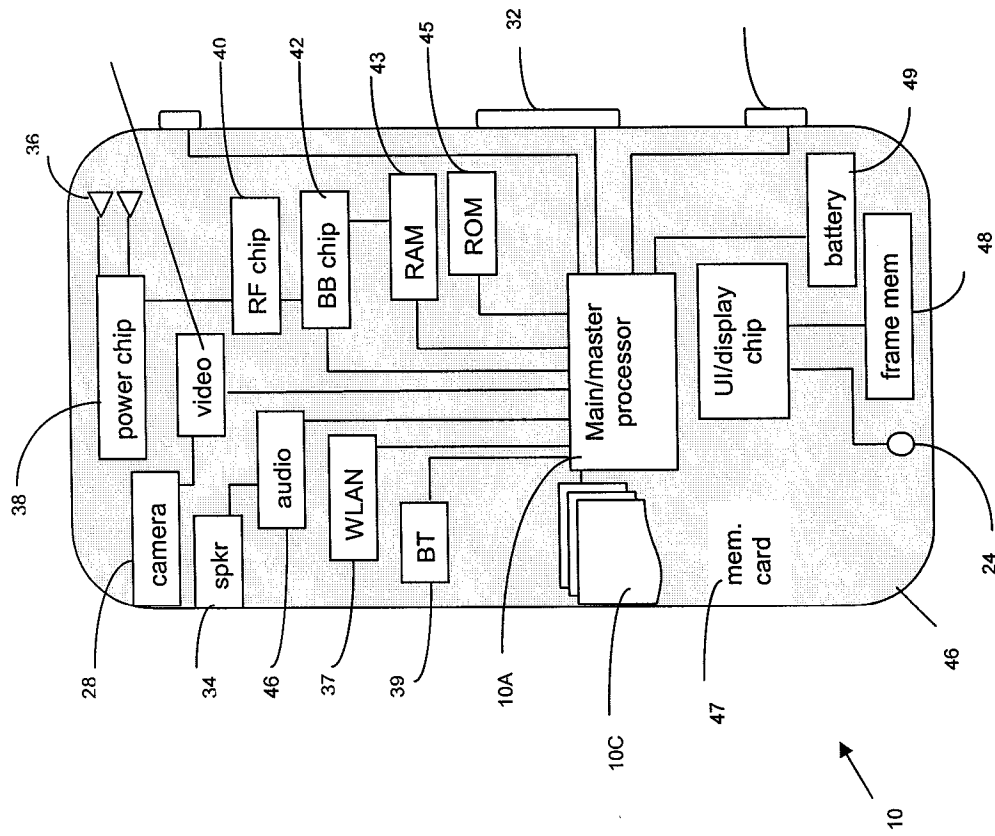
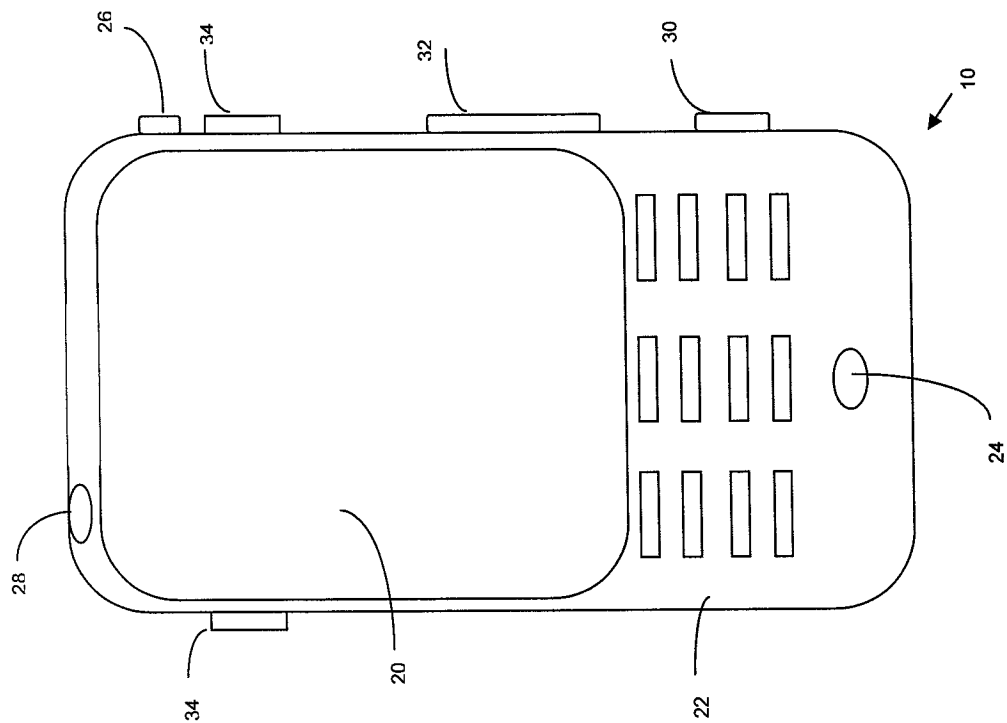


Figure 3B



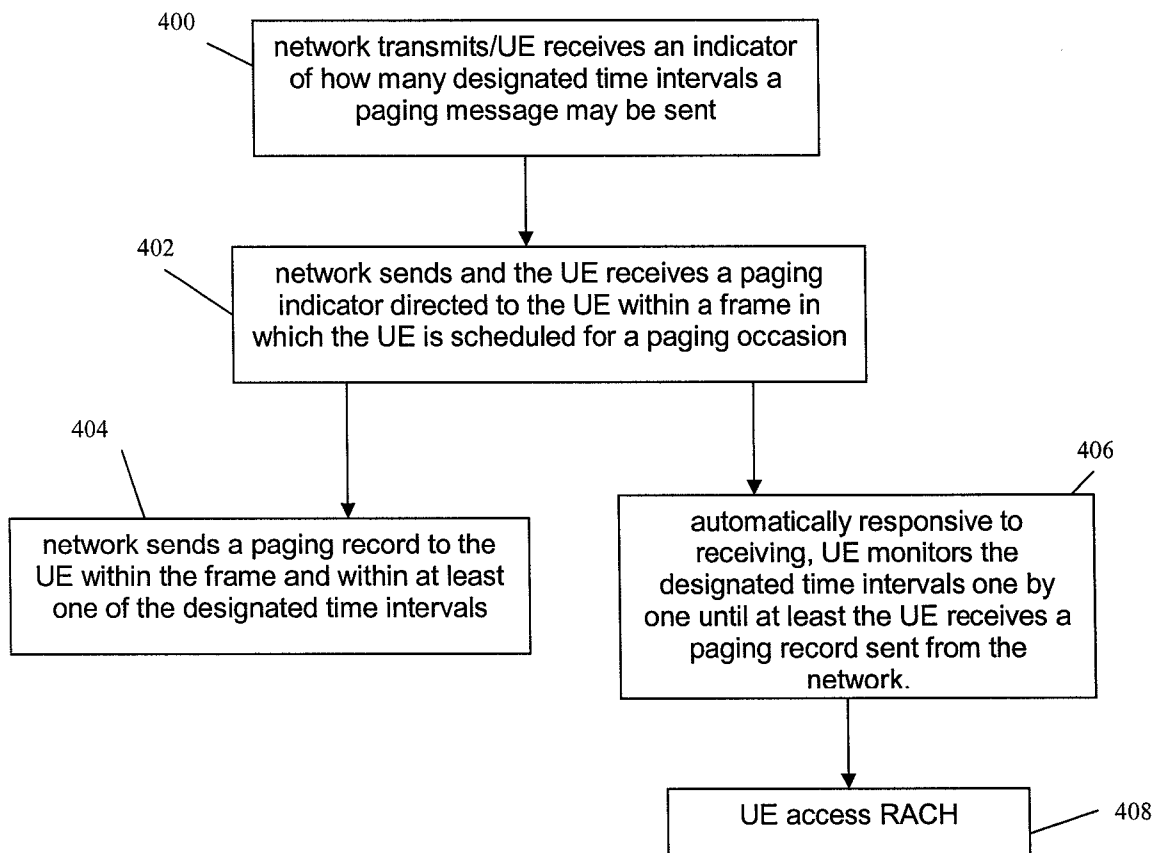


Figure 4

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2008/054768

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W68/02

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 00/57662 A (QUALCOMM INC [US]) 28 September 2000 (2000-09-28) page 3, line 25 - line 31 page 8, line 23 - line 36 -----	1, 10, 12, 21
X A	WO 2007/078172 A (LG ELECTRONICS INC [KR]; LEE YOUNG DAE [KR]; CHUN SUNG DUCK [KR]; JUNG) 12 July 2007 (2007-07-12) page 8, line 19 - page 9, line 5; figure 5 -----	1, 10, 12, 21, 22, 27, 29, 32 2-9, 11, 13-20, 23-26, 28, 30, 31, 33
A	WO 2005/079086 A (QUALCOMM INC [US]; GAAL PETER [US]; TIEDEMANN EDWARD G JR [US]) 25 August 2005 (2005-08-25) paragraph [0007] -----	7, 18
-/--		

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
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- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *G* document member of the same patent family

Date of the actual completion of the international search

20 April 2009

Date of mailing of the international search report

27/04/2009

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2008/054768

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	"Universal Mobile Telecommunications System (UMTS); User Equipment (UE) procedures in idle mode and procedures for cell reselection in connected mode (3GPP TS 25.304 version 7.3.0 Release 7); ETSI TS 125 304" ETSI STANDARDS, LIS, SOPHIA ANTIPOLIS CEDEX, FRANCE, vol. 3-R2, no. V7.3.0, 1 October 2007 (2007-10-01), XP014039982 ISSN: 0000-0001 * paragraph 8.3 * -----	24

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2008/054768

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			EP 1719382 A2	08-11-2006
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