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Description

CLAIM OF PRIORITY

[0001] This application claims the benefit of priority to Indian Application No. 1349/DEL/2014, filed on May 22, 2014, and to U.S. Provisional Application Serial No. 62/021,967, filed on July 8, 2014.

TECHNICAL FIELD

[0002] The present disclosure relates generally to synchronization procedures in wireless devices and, more particularly, to techniques for realizing power savings in synchronization procedures in wireless devices that operate using a prolonged sleep mode.

BACKGROUND

[0003] The following abbreviations are herewith defined, at least some of which are referred to within the following description of the prior art and the present invention.

3GPP Third Generation Partnership Project
BCC Base Station Color Code
BCCH Broadcast Control Channel
BSIC Base Station Identification Code
CCCH Common Control Channel
DB Dummy Burst
DRX Discontinuous Reception
FB Frequency Burst
FCCH Frequency Correction Channel
FDMA Frequency Division Multiple Access
FO Frequency Offset
GERAN GSM EDGE Radio Access Network
GSM Global System for Mobile Communications
ID Identifier
M2M Machine-to-Machine
MS Mobile Station
MTC Machine Type Communication
N Burst Numbers
NB Normal Burst
PSM Power Saving Mode
RACH Random Access Channel
RAU Routing Area Update
RSSI Received Signal Strength Indicator
SB Synchronization Burst
SCH Synchronization Channel
TBF Temporary Block Flow
TDMA Time Division Multiple Access
TSC Training Sequence Code

[0004] In the case of wireless devices, especially mobile devices or mobile stations (MSs), battery capacity may be severely restricted due to constraints on size and weight of the device. As battery capacity is limited, ensuring an optimal power management scheme for these devices is critical, especially for the case of devices such as Machine Type Communications (MTC) devices intended for machine-to-machine (M2M) communication without an external power supply. With a primary objective of exploring different options for realizing power savings in the case of MTC devices, a new study item on "Power Saving for MTC Devices" was agreed upon in the 3GPP Technical Specification Group (TSG) GERAN Meeting #60.

[0005] As networks and wireless devices are driven by independent clocks housed inside the respective entities, proper synchronization is needed for establishing effective communication between the entities. The Global System for Mobile Communications (GSM) is based on Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA), and thus, time and frequency synchronization are needed for proper transmission and reception of information by wireless devices operating on GSM. In addition, with the introduction of MTC devices on wireless networks, in general, there is a dramatically reduced need for how frequently such MTC devices should be reachable for downlink communications. That is, MTC devices do not need to support legacy type paging operation wherein wireless devices can be paged as often as every few seconds. This dramatic reduction in the frequency of reachability for MTC devices introduces the opportunity for substantial power savings in that these types of wireless devices may experience a prolonged period of sleep between any two consecutive instances of reachability. Several methods for realizing prolonged periods of sleep are currently under consideration within 3GPP such as:

- Long Paging cycle (Long DRX)
- Power Saving Mode (PSM)
- Mobile Power Off

[0006] However, the use of such prolonged periods of sleep increases the risk of the wireless device (e.g., MTC device) losing synchronization with the network, because the more time the wireless device remains in the sleep mode, the more the synchronization errors accumulate (i.e., the wireless device stops performing frequent synchronization verification upon entering sleep mode). As such, identifying new methods for wireless devices (e.g., MTC devices) to quickly and efficiently re-acquire synchronization with the network as the wireless devices approach a period of reachability (which starts with the first burst of the paging block associated with a wireless device’s nominal DRX cycle) will be an important aspect of the power management scheme needed for these devices. Legacy methods for re-acquiring synchronization are considered unnecessarily energy intensive and should be subject to significant optimization considering the low mobility anticipated for many MTC devices.

[0007] The conventional method for acquiring synchronization during what is known as a synchronization cycle when a wireless device wakes-up from a sleep cycle be-
fore entering the period of reachability known as a reach-
ability cycle (i.e., before entering the portion of its DRX
cycle during which the wireless device can receive a pag-
ing message) can be referred to as "long sync" and in-
cludes the following:

- Performing a fall sync up procedure where the wire-
less device will read the Frequency Correction Chan-
nel (FCCH), correct the frequency base (and slot
boundary) first, and then read the Synchronization
Channel (SCH) for time frame number and right cell
identification.

- Reading the Broadcast Control Channel (BCCH) or
 Common Control Channel (CCCH) messages. How-
ever, because the FCCH and SCH bursts appear
very infrequently in the GSM 51-multiframe (i.e.,
onece over 10 TDMA frames), the wireless device
will spend a lot of time looking for the FCCH and
SCH and then using the FCCH and SCH to ad-
just/verify the synchronization.

[0008] However, this conventional synchronization
method is far too complex, processing time intensive,
and energy consuming considering the limited mobility
expected for the large numbers of MTC devices, and
thus, this conventional synchronization method can be
viewed as non-optimized. Moreover, if the wireless de-
vice (e.g., MTC device) has been in sleep state for a long
time, the frequency offset (FO) may be too large (e.g.,
>10 KHz) to allow for successful reception of the wireless
device’s paging block as determined according to the
wireless device’s nominal DRX cycle. In this case, the
wireless device has to do several FCCH receptions be-
fore the wireless device can receive the FCCH properly
where the FO converges to < 100 Hz, which is needed
for subsequently performing a proper SCH decoding. If
the wireless device is usable to complete the synchroni-
zation procedure before reception of the wireless de-
vice’s paging block as determined according to the wire-
less device’s nominal DRX cycle, then the wireless de-
vice will miss the paging block reception opportunity for
which the wireless device awoke.

communication (MTC) device for handling long discon-
 tinuous reception (DRX) cycles/sleep lengths. The MTC
device uses an adjustment window period/receiving win-
dow length as a time required by the MTC device to wake-
up from the long sleep and synchronize with the network
and may end when the MTC device may have received
the paging or may end after a period of time (such as a
receiving window length). The MTC device may generate
the adjustment window period using a long sleep length,
a clock drift rate, and a wake up time.

SUMMARY

[0010] A wireless device and method which address
the problems associated with the conventional synchro-
nization method are described in the present application.
Advantageous embodiments of the wireless device and
the method are further described in the present applica-
tion.

[0011] In one aspect, a wireless device is configured
with a DRX cycle which comprises a reachability cycle,
sleep cycle, and a synchronization cycle. The wireless
device comprises a processor, and a memory that stores
processor-executable instructions, wherein the proces-
sor interfaces with the memory to execute the processor-
executable instructions, whereby the wireless device is
operable to implement a compute operation and a set
operation. In the compute operation, the wireless device
data, during the reachability cycle, a time (T_W) for
the synchronization cycle during which a synchronization
procedure is to be performed. In the set operation, the
wireless device sets a timer with a time (T_d) based on
the computed time (T_w) to wake up from the sleep cycle
and perform the synchronization procedure. The reach-
ability cycle occurs before the sleep cycle, and the sleep
cycle occurs before the synchronization cycle. In one em-
bodiment, the wireless device being operable to compute
the time (T_W) for the synchronization cycle includes being
operable to: (1) estimate a total accumulated frequency
drift of the sleep cycle, wherein the total accumulated
drift is equal to Δf*T_s, wherein Δf is a frequency
drift per unit time of a local oscillator in the wireless de-
vice, and wherein T_s is an estimated duration of the sleep
cycle; (2) compute a number of FBs, SBs, and NBs to be
received to enable a correction of the estimated total ac-
cumulated frequency drift; and (3) compute the time (T_W)
for the synchronization cycle based on (i) a known frame
structure which indicates how many FBs, SBs, and NBs are
expected during a certain period of time, (ii) a known
amount of frequency drift that can be corrected from each
reception of FB, SB, and NB, and (iii) the computed
number of FBs, SBs, and NBs to be received to enable
the correction of the estimated total accumulated fre-
quency drift. The wireless device operating in this manner
has the advantage of reducing the energy consumption of
the wireless device’s battery.

[0012] In another aspect, a method is implemented in
a wireless device configured with a DRX cycle which
comprises a reachability cycle, a sleep cycle, and a synchro-
nization cycle. The method comprises a computing
step and a setting step. In the computing step, the wire-
less device computes, during the reachability cycle, a
time (T_W) for the synchronization cycle during which a
synchronization procedure is to be performed. In the set-
ting step, the wireless device sets a timer with a time (T_d)
based on the computed time (T_w) to wake up from the sleep
cycle and perform the synchronization procedure.
The reachability cycle occurs before the sleep cycle, and
the sleep cycle occurs before the synchronization cycle.
In one embodiment, computing the time (T_W) for the syn-
crhonization cycle further comprises: (1) estimating a to-
tal accumulated frequency drift of the sleep cycle, where-
in the total accumulated frequency drift is equal to \( \Delta f \cdot T_S \), wherein \( \Delta f \) is a frequency drift per unit time of a local oscillator in the wireless device, and wherein \( T_S \) is an estimated duration of the sleep cycle; (2) computing a number of FBs, SBs, and NBs to be received to enable a correction of the estimated total accumulated frequency drift; and (3) computing the time \( (T_W) \) for the synchronization cycle based on (i) a known frame structure which indicates how many FBs, SBs, and NBs are expected during a certain period of time, (ii) a known amount of frequency drift that can be corrected from each reception of FB, SB, and NB, and (iii) the computed number of FBs, SBs, and NBs to be received to enable the correction of the estimated total accumulated frequency drift. The method has the advantage of reducing the energy consumption of the wireless device’s battery.

[0013] Additional aspects of the invention will be set forth, in part, in the detailed description, figures and any claims which follow, and in part will be derived from the detailed description, or can be learned by practice of the invention. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention as disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] A more complete understanding of the present invention may be obtained by reference to the following detailed description when taken in conjunction with the accompanying drawings:

FIGURE 1 is a diagram of an exemplary wireless communication network in accordance with the present disclosure;
FIGURE 2 is a flowchart of a method implemented by a wireless device in accordance with an embodiment of the present disclosure;
FIGURE 3 is a block diagram illustrating structures of an exemplary wireless device configured in accordance with an embodiment of the present disclosure;
FIGURE 4 is diagram illustrating a DRX periodicity, a sleep duration, and a dynamic short sync up interval associated with the wireless device in accordance with an embodiment of the present disclosure;
FIGURES 5A-5B is a flowchart of another method implemented by the wireless device in accordance with an embodiment of the present disclosure;
FIGURE 6 is a diagram illustrating an Intermediate short sync procedure (at time instant \( T_{sd} \)) that is implemented when the total accumulated FO over sleep duration \( T_S \) is greater than a Threshold "X" per the method illustrated in FIGURES 5A-5B in accordance with an embodiment of the present disclosure; and,
FIGURE 7 is a diagram illustrating a short sync before CCCH reception using FB, SB, or NB over time window \( T_W \) per the method illustrated in FIGURES 5A-5B in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0015] To explain the technical features of the present disclosure, a discussion is provided first to describe an exemplary wireless communication network 100 which includes multiple wireless devices 1041, 1042, 1043...104n, each of which is configured in accordance with the present disclosure (see FIGURE 1). Then, a discussion is provided to explain the functionality and configuration of the wireless devices 1041, 1042, 1043...104n in accordance with the present disclosure (see FIGURES 2-3). Thereafter, a discussion is provided to explain in more detail various concepts associated with the functionality and configuration of the wireless devices 1041, 1042, 1043...104n of the present disclosure (see FIGURES 4-7).

Exemplary Wireless Communication Network 100

[0016] Referring to FIGURE 1, there is illustrated an exemplary wireless communication network 100 in accordance with the present disclosure. The wireless communication network 100 includes multiple wireless access nodes 1021 and 1022 (only two illustrated), multiple wireless devices 1041, 1042, 1043...104n, and a core network 106 (e.g., EGPRS core network 106). The wireless communication network 100 and its associated components also include many well-known components, but for clarity, only the components needed to describe the features of the present disclosure are described herein. Further, the wireless communication network 100 is described herein as being an GSM/EGPRS wireless communication network 100 which is also known as an EDGE wireless communication network 100. However, those skilled in the art will readily appreciate that the techniques of the present disclosure, which are applied to the GSM/EGPRS wireless communication network 100, are generally applicable to other types of wireless communication systems, including, for example, WCDMA, LTE, and WiMAX systems.

[0017] The wireless communication network 100 includes the wireless access nodes 1021 and 1022 (only two illustrated) that provide network access to the wireless devices 1041, 1042, 1043...104n. In this example, the wireless access node 1021 is providing network access to wireless device 1041, while the wireless access node 1022 is providing network access to wireless devices 1042, 1043...104n. The wireless access nodes 1021 and 1022 are connected to the core network 106 (e.g., EGPRS core network 106). The core network 106 is connected to an external Packet Data Network (PDN) 108, such as the Internet, and a server 110 (only one illustrated). The wireless devices 1041, 1042, 1043...104n may communicate with one or more servers 110 (only one
illustrated) connected to the core network 106 and/or the PDN 108.

[0018] The wireless devices 104₁, 104₂, 104₃...₁₀₄ₙ may refer generally to an end terminal (user) that attaches to the wireless communication network 100, and may refer to either a MTC device or a non-MTC device. Further, the term "wireless device" is generally intended to be synonymous with the term "User Equipment," or UE, as that term is used by the 3rd-Generation Partnership Project (3GPP), and includes standalone wireless devices, such as terminals, cell phones, smart phones, tablets, and wireless-equipped personal digital assistants, as well as wireless cards or modules that are designed for attachment to or insertion into another electronic device, such as a personal computer, electrical meter, etc.

[0019] Likewise, the wireless access nodes 102₁ and 102₂ may refer in generally to a base station or central node in the wireless communication network 100, and may refer to wireless access nodes 102₁ and 102₂ that are controlled by a physically distinct radio network controller as well as to more autonomous access points, such as the so-called evolved Node Bs (eNodeBs) in Long-Term Evolution (LTE) networks.

[0020] Each wireless device 104₁, 104₂, 104₃...₁₀₄ₙ may include a transceiver circuit 110₁, 110₂, 110₃...₁₁₀ₙ for communicating with the wireless access nodes 102₁ and 102₂, and a processing circuit 112₁, 112₂, 112₃...₁₁₂ₙ for processing signals transmitted from and received by the transceiver circuit 110₁, 110₂, 110₃...₁₁₀ₙ and for controlling the operation of the corresponding wireless device 104₁, 104₂, 104₃...₁₀₄ₙ. The transceiver circuit 110₁, 110₂, 110₃...₁₁₀ₙ may include a transmitter 114₁, 114₂, 114₃...₁₁₄ₙ and a receiver 116₁, 116₂, 116₃...₁₁₆ₙ, which may operate according to any standard, e.g., the GSM/EDGE standard. The processing circuit 112₁, 112₂, 112₃...₁₁₂ₙ may include a processor 118₁, 118₂, 118₃...₁₁₈ₙ and a memory 120₁, 120₂, 120₃...₁₂₀ₙ for storing program code for controlling the operation of the corresponding wireless device 104₁, 104₂, 104₃...₁₀₄ₙ.

[0022] Referring to FIGURE 2, there is a flowchart of a method 200 in the wireless device 104₁ (for example), which is configured with a discontinuous reception (DRX) cycle 400, which comprises a reachability cycle 402, a sleep cycle 404, and a synchronization cycle 406 in accordance with an embodiment of the present disclosure (see FIGURE 4 for graphical illustration of the DRX cycle 400 comprising the reachability cycle 402, the sleep cycle 404, and the synchronization cycle 406). Beginning at step 202, the wireless device 104₁, during the reachability cycle 402, computes a time (Tₛ₇) (e.g., an amount of time Tₛ needed) for the synchronization cycle 406 during which a synchronization procedure 201 (also referred to herein as "short syncup," "short sync up," "short synch," and/or "short sync") is to be performed. In one example, the computing step 202 comprises steps 202a, 202b, and 202c, although other examples of the synchronization procedure 201 may comprise a subset or superset of these steps, possibly in combination with other steps. At step 202a, the wireless device 104₁ estimates a total accumulated frequency drift of the sleep cycle 404 (e.g., the total accumulated frequency drift that occurs during the sleep cycle 404), wherein the total accumulated frequency drift is equal to ΔTₛ₇, wherein ΔTₛ is a frequency drift per unit time of a local oscillator (LO) 205 (e.g., the frequency drift inherent to the performance of the local oscillator 205) in the wireless device 104₁, and wherein Tₛ₇ is an estimated duration of the sleep cycle 404. Frequency drift is also referred to herein as "frequency offset," "FO," "frequency error," and/or "frequency deviation." Time duration is also referred to herein as "time window," "time period," and/or "time interval." It is to be noted that the value estimated for Tₛ₇ may be adjusted for a next iteration of the method 200 based on what the wireless device 104₁ determines to be the nominal amount of time Tₛ needed for the synchronization cycle 406. At step 202b, the wireless device 104₁ computes a number of FBs, SBs, and NBs (e.g., the number of FBs, SBs, and NBs that are needed) to be received to enable a correction of the estimated total accumulated frequency drift. At step 202c, the wireless device 104₁ computes the time (Tₛ₇) for the synchronization cycle 406 based on (1) a known frame structure which indicates how many FBs, SBs, and NBs are expected (e.g., the number expected to occur, appear, or be received) during a certain period of time, (2) a known amount of frequency drift that
can be corrected from each reception of FB, SB, and NB, and (3) the computed number of FBs, SBs, and NBs to be received to enable the correction of the estimated total accumulated frequency drift. The reachability cycle 402 occurs before the sleep cycle 404, which occurs before the synchronization cycle 406. The computing step 202 is discussed in more detail below with respect to FIGURES 4-7.

[0023] At step 204, the wireless device 104, sets a timer with a time \( T_d \) based on the computed time \( T_W \) to wake up from the sleep cycle 404 and perform the synchronization procedure 201. In one example, the synchronization procedure 201 comprises steps 204a, 204b, 204c, 204d, 204e, and 204f, although other examples of the synchronization procedure 201 may comprise a subset or superset of these steps, possibly in combination with other steps. At step 204a, the wireless device 104, synchronizes a frequency and a time with a camped cell (e.g., wireless access node 102 of FIGURE 1). At step 204b, the wireless device 104, determines if the wireless device 104, is receiving a signal associated with a previously camped cell or a new camped cell by checking a SB (i.e., specifically checking the value of the Base Station Color Code (BCC) portion of the Base Station Identification Code (BSIC) of the SB, which indicates a Training Sequence Code (TSC) number) or by checking a TSC number in any received NB. At step 204c, the wireless device 104, receives in-phase and quadrature (I, Q) samples. At step 204d, the wireless device 104, estimates a Received Signal Strength Indicator (RSSI) value using the received in-phase and quadrature (I, Q) samples. At step 204e, the wireless device 104, verifies if a C1/C2 criterion is fulfilled using the estimated RSSI value. At step 204f, the wireless device 104, schedules a Common Control Channel (CCCH) reading or a Routing Area Update (RAU) during the next reachability cycle 402 if the C1/C2 criterion is fulfilled. C1 is a path loss criterion parameter for cell selection, and C2 is a path loss criterion parameter for cell reselection obtained by calculation of the receiving level and number of parameters. C1/C2 criterion is path loss for cell selection/reselection criterion. C1 and C2 are discussed, for example, in 3GPP Technical Specification (TS) 43.022 V11.0.0, entitled "Functions related to Mobile Station (MS) in idle mode and group receive mode (Release 11)". The synchronization procedure 201 is discussed in more detail below with respect to FIGURES 4-7.

[0024] At step 206, the wireless device 104, wakes up one or more times during the sleep cycle 404 to perform one or more intermediate synchronization procedures 203 (also referred to herein as "intermediate short sync", "intermediate short synch", and/or "intermediate short sync") when the estimated total accumulated frequency drift determined in step 202a exceeds a predetermined threshold "X". In one case, in step 206a, the wireless device 104, can determine when to perform each of the one or more intermediate synchronization procedures 203 based on a mobility of the wireless device 104. The determination of when to wake up to perform the intermediate synchronization procedure 203 is discussed in more detail below with respect to FIGURES 4-7.

[0025] Referring to FIGURE 3, there is a block diagram illustrating structures of an exemplary wireless device 104, (for example), which is configured in accordance with an embodiment of the present disclosure. In an embodiment, the wireless device 104, may comprise a compute \( T_W \) module 302, a set timer with time \( T_d \) module 304, and an intermediate wake-up module 306. The compute \( T_W \) module 302 may be configured to compute, during the reachability cycle 402, a time \( T_w \) (e.g., an amount of time \( T_W \) needed) for the synchronization cycle 406 during which the synchronization procedure 201 is to be performed. In one example, the compute \( T_W \) module 302 may be configured to (1) estimate a total accumulated frequency drift of the sleep cycle 404 (e.g., the total accumulated frequency drift that occurs during the sleep cycle 404), wherein the total accumulated frequency drift is equal to \( \Delta fT_S \), wherein \( \Delta f \) is a frequency drift per unit time of a local oscillator 205 (e.g., the frequency drift inherent to the performance of the local oscillator 205) in the wireless device 104, and wherein \( T_S \) is an estimated duration of the sleep cycle 404; (2) compute a number of FBs, SBs, and NBs (e.g., the number of FBs, SBs, and NBs that are needed) to be received to enable a correction of the estimated total accumulated frequency drift; and (3) compute the time \( T_W \) for the synchronization cycle 406 based on (i) a known frame structure which indicates how many FBs, SBs, and NBs are expected (e.g., the number expected to occur, appear, or be received) during a certain period of time, (ii) a known amount of frequency drift that can be corrected from each reception of FB, SB, and NB, and (iii) the computed number of FBs, SBs, and NBs to be received to enable the correction of the estimated total accumulated frequency drift. The set timer with time \( T_d \) module 304 may be configured to set the timer with the time \( T_d \) based on the computed time \( T_W \) to wake up from the sleep cycle 404 and perform the synchronization procedure 201. It is to be noted that the length of \( T_W \) is determined based on the need that the synchronization procedure 201 during \( T_W \) will have a high probability of succeeding without resorting to using the long sync procedure (i.e., the conventional method for acquiring synchronization). The intermediate wake-up module 306 may configure a timer with a time \( T_{RU} \) in order to wake up one or more times during the sleep cycle 404 to perform one or more intermediate synchronization procedures 203 when the estimated total accumulated frequency drift experienced during \( T_S \) exceeds a predetermined threshold "X". This will then help ensure that there is a high probability that the total accumulated frequency drift that exists at the end of the sleep cycle 404 can be successfully corrected during \( T_W \) without the wireless device 104, having to resort to using the long sync procedure.

[0026] As those skilled in the art will appreciate, the
Computing the amount of time (referred to herein as "short sync") has been described above with respect to FIGURE 2. This method 200 may generally include the following steps:

- Computing the amount of time (referred to herein as the "short sync up interval") immediately prior to entering a period of reachability, referred to herein as "short sync" has been described above with respect to FIGURE 2. This method 200 may generally include the following steps:

- Predicting the local oscillator 205 (i.e., local clock) frequency deviation ($\Delta f$) occurring over TS, which means the wireless device 104 has to wake up at the start of every $T_L$ time period referred to herein as the reachability cycle 402 (e.g., FIGURE 5A’s step 502). However, in order to complete the short sync up activities before this CCCH block reading (as that will be needed to help maximize the probability of successful CCCH block reception), the wireless device 104 has to wake up early enough prior to receiving the first burst of the wireless device 104’s nominal paging block to perform the synchronization procedure 201 during the synchronization cycle 406. To accomplish this, the wireless device 104 dynamically computes during the previous reachability cycle 402 the short sync up interval (denoted as $T_W$), which is the needed length or time duration of the next short sync up interval (synchronization cycle 406), and sets a timer (e.g., timer 207 of the wireless device 104 in FIGURE 1) with a time ($T_d$) to wake up at the start of the time period $T_W$ (e.g., FIGURE 2’s steps 202 and 204, and FIGURE 5A’s step 504). In addition, once the wireless device 104 begins reading the first burst of the wireless device 104’s nom-
nal paging block, the wireless device 104, enters a period of reachability denoted as T_R (reachability cycle 402) at the end of which the wireless device 104, computes the next short sync up interval (denoted as T_W) and then once again enters a period of sleep (sleep cycle 404). Here, the post sync up (also referred to as "post syncup") activity time duration is denoted as T_R (reachability cycle 402), during which time the wireless device 104, performs several other tasks as may be required, including a CCCH block reading and/or a Routing Area Update (RAU). Effectively, the wireless device 104, stays in the sleep cycle 404 for a duration of T_S = T_L - T_W - T_R. The shorter the short sync up interval (T_W), and the greater the length of T_S, the better the battery energy saving. This is because the wireless device 104, spends more time in sleep mode, where the wireless device 104, can cut the voltages and clocks to different operational modules for achieving optimum power saving.

[0029] The DRX cycle 400 includes a limited period of reachability (reachability cycle 402) followed by a prolonged period of sleep (sleep cycle 404) and then the short sync up interval (synchronization cycle 406). Just before going to sleep, the wireless device 104, will set the timer (e.g., timer 207 of the wireless device 104, in FIGURE 1) with the time (T_d) to wake up after time T_S, which is T_R time ahead of the start of the next DRX cycle that starts at the end of the short sync up interval (synchronization cycle 406). In the short sync up interval (T_W), there will be N bursts (i.e., T_W includes an integer number of consecutive 577 µs bursts). Thus, typically, the wireless device 104, will be receiving N number of bursts prior to receiving the first burst of the wireless device 104, nominal paging block (on the CCCH) at the start of the wireless device 104, DRX cycle length T_L. Accordingly, N is the total number of bursts (slots) that the wireless device 104, will receive on the tuned cell broadcast frequency (i.e., camped cell), for example, all the slots (slot-0 to slot-7) over the TDMA frames and not just slot-0. Here, the short sync method 200 helps to dynamically decide how many bursts ahead of the start of the wireless device 104, 's next DRX cycle length T_L, the wireless device 104, should wake up to perform the frequency and time synchronization.

[0030] As GSM is a TDMA and FDMA based system, time and frequency synchronizations are needed for proper transmission and reception of user plane and signaling information. During the DRX sleep cycle 404, the wireless device 104, does not transmit or receive any bursts, so the wireless device 104, 's local time (counter) and frequency base gradually drift, and corresponding errors accumulate over time. As such, upon waking up to perform the synchronization procedure 201, the wireless device 104, needs to estimate and correct the accumulated error (as best as possible) before starting the communication (reading the first burst of a paging block or performing an uplink transmission) (e.g., FIGURE 2's step 202a, FIGURE 5A's step 504a). Accordingly, the wireless device 104, will wake up a few slots (say 'N' slots) ahead of the scheduled paging block reception start time which is determined according to the wireless device 104, 's nominal DRX cycle 400 (i.e., these few slots are referred to herein as the short sync up interval T_W).

[0031] This short sync up interval T_W (synchronization cycle 406), with duration N*577 µsec, will be dynamically computed by the wireless device 104, based on the start time of the next DRX cycle 400, and the expected FB, SB, NB's presence in the portion of the TDMA 51-multi-frame structure occurring just before the start time of the next DRX cycle 400 of the presently camped cell broadcast frequency. Plus, the wireless device 104, generally knows, or can acquire or determine, the drift of the wireless device 104, 's local oscillator 205 over time such that the wireless device 104, can predict and estimate the coarse value of Frequency Offset (FO) over the sleep time interval (also referred to herein as accumulated FO over sleep) (e.g., FIGURE 2's step 202a, FIGURE 5A's step 504a). Accordingly, the wireless device 104, can perform the following:

(a) Estimate the accumulated FO over sleep - the wireless device 104, knows the rate of linear frequency drift of the local oscillator 205 over time (i.e., Δf). If the estimated sleep duration is T_S, then the total accumulated frequency drift over sleep duration will be T_S*Δf. So, the accumulated FO over sleep = T_S*ΔF (e.g., FIGURE 2's step 202a and FIGURE 5A's step 504a).

(b) Compute the number of FB, SB, and NB (e.g., N1, N2, and N3 respectively) expected over the 'N' bursts (slots) occurring just before the actual start of the next DRX cycle 400. This means that in the time interval T_W, there will be N1 number of FBs, and N2 number of SBs, and N3 number of NBs present/appearing/occurring. These 'N' bursts are counted using bursts from all timeslots occurring from the start of T_W until the first burst of the wireless device 104, 's nominal paging block (i.e., not just bursts occurring in timeslot 0). This is possible because the the wireless device 104, knows the TDMA frame structure, which indicates how many FBs, SBs, and NBs can be expected to be received (e.g., appear in the TDMA frame structure) during a period of time (e.g., FIGURE 2's step 202c(i) and FIGURE 5A's step 504c(i)).

(c) Compute the number of FBs, SBs, and NBs to be received to enable the correction of the estimated total accumulated frequency drift (accumulated FO over sleep) (e.g. FIGURE 2's step 202b and FIGURE 5A's step 504b). This is possible because it is known that if a FB is detected in the short sync up interval (T_W), then the amount of frequency drift that could be corrected for one FB = Δf1. Similarly, if a SB is detected in the short sync up interval (T_W), then the amount of frequency drift
that could be corrected for one SB = \Delta f_2, and if an NB is detected in the short sync up interval (T_W), then the amount of frequency drift that could be corrected for one NB = \Delta f_3 (e.g., FIGURE 2’s step 202c(ii) and FIGURE 5A’s step 504c(ii)). Hence, the wireless device 104, can determine what the wireless device 104, needs to receive in order to fulfill the synchronization need by correcting the estimated accumulated FO over sleep. In particular, the wireless device 104, can make the following determination: N1*(\Delta f_1) + N2*(\Delta f_2) + N3*(\Delta f_3) \geq \text{estimated accumulated FO over sleep}, where N1 is the number of FBs, N2 is the number of SBs, and N3 is the number of NBs expected over the ‘N’ bursts during the short sync up interval (synchronization cycle 406) immediately preceding the first burst of the pag-
in block associated with the wireless device 1041's 406) immediately preceding the first burst of the pag-
ting the short sync up interval (synchronization cycle 406) immediately preceding the first burst of the pag-
ning cycle 406 and when to wake up from the sleep cycle 404 to perform the synchronization procedure 201

(e) If the ‘accumulated FO over sleep’ over the sleep duration T_s is greater than a threshold value “X,” then the wireless device 104, need not perform the intermediate synchronization procedure 203 and can wake up at time T_w before T_l and perform the synchronization procedure 201 for the duration of T_w before the CCCH reception (e.g., FIG-
URE 5B’s steps 506, 514, and 516). This process is also illustrated in FIGURE 7.

(f) The wireless device 104, would perform the method 500 illustrated in FIGURES 5A-5B during each DRX cycle 400.

As a part of the synchronization procedure 201, the wireless device 104, performs the frequency offset estimation, correction, and burst boundary correction (e.g., FIGURE 2’s step 204a). The wireless device 104, can use the FB, SB, and NB for this purpose. In this regard, the FB has all known sequences, the SB has 64-bit known sequences (i.e., all SBs in a GSM system use the same 64-bit training sequence), and the NB has 26-bit known sequences (i.e., there are 8 possible 26-bit training sequences inside the NB). In an NB, out of the eight possible Training Sequence Codes (TSCs) (i.e., the 26-bit training sequences), which one is used can be determined based on the previously camped cell’s ID (i.e., based on the serving cell used during the previous synchronization procedure 201), as discussed, for example, in 3GPP TS 45.002 v12.1.0, entitled “Multiplexing and multiple access on the radio path (Release 12”). Generally, a wireless device can use any standard fre-

and multiple access on the radio path (Release 12)”.

(1) U.S. Patent Publication No. 2014/0226647 to Das et

al.; (2) P.J. Kootsookos, “A Review of the Frequency Es-
timation and Tracking Problems,” Feb. 21, 1999 (availa-
The following steps may be followed in the synchronization procedure 201:

1. Before going to sleep, the wireless device 1041 performs a first intermediate synchronization procedure 203 and then starts a timer with a time = "Tint1," where the value of "Tint1" is determined by the time remaining until the start of the N bursts immediately preceding the first burst of the paging block associated with the wireless device 1041's nominal DRX cycle 400.

2. At the wake-up, the wireless device 1041 may apply the pre-estimated frequency offset accumulated during sleep and then receive N bursts during the short sync up interval and try to correct any remaining frequency error and time error, as described above (e.g., FIGURE 2's step 204a). It is to be noted that the wireless device 1041 could perform the same steps when implementing the intermediate synchronization procedure 203 at expiration of time Tint as the wireless device 1041 does when performing the synchronization procedure 201 at expiration of time Td.

3. During the short sync up interval, the wireless device 1041 also confirms whether the wireless device 1041 is receiving the previously camped cell's signal or a new camped cell's signal by checking the SB (if the SP appears/occurs in the set of N bursts) or by checking the TSC number on any received NB over that cell broadcast frequency as described above (e.g., FIGURE 2's step 204b).

4. During the short sync up interval, the wireless device 1041 is also receiving the in-phase and quadrature (I, Q) samples from the camped cell frequency and uses them to estimate the Received Signal Strength Indicator (RSSI) value, and using that, the wireless device 1041 also verifies the C1/C2 criterion (e.g., FIGURE 2's steps 204c, 204d, and 204e).

5. If the C1/C2 criterion is fulfilled, the cell is confirmed via the NB's TSC number or via the SB's BSIC, and needed frequency and time synchronization is performed, at which point the wireless device 1041 will schedule the CCCH reading (i.e., the wireless device 1041 schedules the reading of the wireless device 1041's paging block determined according to the wireless device 1041's nominal DRX cycle 400) or a Routing Area Update (RAU) (e.g., FIGURE 2's step 204f).

For example, if the threshold value "X" = 40% of the length of the nominal DRX cycle 400, then (a) just prior to going to sleep, the wireless device 1041 sets a timer with a time = "Tint1," where the value of "Tint1" is determined by the threshold value "X," (b) upon expiry of "Tint1," the wireless device 1041 performs a first intermediate synchronization procedure 203 and then starts a timer with a time = "Tint2," where the value of "Tint2" is determined by the threshold value "X," (c) upon expiry of "Tint2," the wireless device 1041 performs a second intermediate synchronization procedure 203 and then starts a timer with a time = "Tint3," where the value of "Tint3" is determined by the time remaining until the start of the N bursts immediately preceding the first burst of the paging block associated with the wireless device 1041's nominal DRX cycle 400, and (d) upon expiry of "Tint3," the wireless device 1041 performs a third intermediate synchronization procedure 203.
energy. Additionally, the last used serving cell might not be the best cell to stay camped-on. However, if the wireless device 104₁, is managing to synchronize with that last used serving cell and the C1/C2 criterion is fulfilled, that last used serving cell may be considered as a sufficiently good cell to stay camped-on to receive paging messages or to start an uplink Random Access Channel (RACH) transmission. Once a communication link is established (i.e., a Temporary Block Flow (TBF) is set up), the wireless device 104₁ might eventually move to the best suitable cell as per legacy cell re-selection procedure.

[D0035] Due to mobility, the wireless device 104₁ might change the cell from time to time. As discussed above, during the synchronization procedure 201, the wireless device 104₁ tries to determine whether the wireless device 104₁ has changed the cell or still remains in the same cell (e.g., FIGURE 2's step 204b). To accomplish this, the wireless device 104₁ checks the TSC number in the NB or the TSC number indicated by the BSIC of the SB of the BCCH frequency. As mentioned above, during the synchronization procedure 201, the wireless device 104₁ receives several NBs and during that time, the wireless device 104₁ detects whether the TSC number present in the NB is the same as, or different from, the previous time detected TSC number in the NB. If the TSC number is the same as expected, then that indicates the wireless device 104₁ is still monitoring the same cell’s signal and along with that, the C1/C2 criterion confirms further that the wireless device 104₁ is still in the previously connected cell and the signal strength (RSSI) of that cell is good enough to be camped on to monitor CCCH or perform an RAU.

[D0036] The length of the intermediate short sync interval (started at expiration of time Tₚₕ) is also determined by the mobility of the wireless device 104₁. There could be several ways by which the wireless device 104₁ can determine or acquire the wireless device 104₁’s mobility criteria or rate of mobility. For instance, the wireless device 104₁ can be designed to be stationary. In this case, the wireless devices 104₁ can have a pre-programmed device configuration flag which indicates that, and during the dynamic estimation of a short sync up interval, nothing specific to mobility needs to be considered. On the other hand, if the wireless device 104₁ is flagged to be a mobile device (e.g., the wireless device 104₁ is not pre-programmed as a stationary device), then based on the wireless device 104₁’s known mobility rate (e.g., detected as Low, Medium, or High), the time Tₚₕ at which to start a short sync up interval could be determined by taking into account the time/frequency synchronization need of performing a long sync procedure (due to an increased probability of the synchronization procedure 201 failing due to device mobility) and possibly, also the estimated time to read the BCCH and perform an RAU (e.g., for the high mobility scenario).

[D0037] During the intermediate synchronization procedure 203, if the wireless device 104₁ determines that the wireless device 104₁ has changed the location (e.g., as a result of TSC analysis), then immediately (e.g., without a delay) a long sync procedure, and when necessary, also an RAU, can be performed and then followed by the synchronization procedure 201 during the next synchronization procedure to keep the wireless device 104₁ always in sync and properly linked to a reasonably good cell at any point of time.

[D0038] Furthermore, if the setting of the timer with the time Tₚₕ is such that it results in the synchronization cycle (Tₜₜₕ) 406 not being long enough to perform a long sync procedure, and the synchronization procedure 201 results in the wireless device 104₁ determining that a cell change has occurred, then the wireless device 104₁ may not be ready in time to read a paging block during the reachability cycle 402 in accordance to the wireless device 104₁’s nominal DRX cycle 400. To address this situation, the wireless device 104₁ implementation may also allow for detecting periods of mobility interspersed with periods of no (or low) mobility and adjusting the setting of the timer with the time Tₚₕ accordingly. For example, during periods of high mobility, the length of Tₜₜₕ will be increased, resulting in (a) a shorter sleep duration Tₛ, and (b) a more extensive set of tasks being performed when waking up at time = Tₚₕ, with the net result being a reduced power savings during these periods. In high mobility scenarios, the synchronization cycle (Tₜₜₕ) 406 needs to be longer so the wireless device 104₁, can, in the event of the synchronization procedure 201 failing, still have enough time to perform a long sync procedure and subsequent RAU signaling to ensure such that the core network 106 will page the wireless device 104₁ in the correct Routing Area.

Some Advantages of the Disclosed Techniques

[D0039] The disclosed optimized methods 200 and 500 (i.e., short sync; synchronization procedure 201) used for acquiring synchronization allows for a significantly reduced amount of processing in a wireless device 104₁, and therefore, significantly reduced energy consumption, as compared to conventional synchronization methods. The disclosed optimized methods 200 and 500 may also be critical for cases where the wireless device 104₁ makes use of prolonged periods of sleep (e.g., MTC devices which downlink reachability can be quite infrequent and/or DRX cycle length ranges from multiple minutes to hours), since the energy savings achievable by prolonging the sleep period alone may not be sufficient for realizing the targeted battery lifetimes for these devices (e.g., months to years).

[D0040] Those skilled in the art will appreciate that the use of the term "exemplary" is used herein to mean "illustrative," or "serving as an example," and is not intended to imply that a particular embodiment is preferred over another or that a particular feature is essential. Likewise, the terms "first" and "second," and similar terms, are used simply to distinguish one particular instance of an item
or feature from another, and do not indicate a particular order or arrangement, unless the context clearly indicates otherwise. Further, the term "step," as used herein, is meant to be synonymous with "operation" or "action." Any description herein of a sequence of steps does not imply that these operations must be carried out in a particular order, or even that these operations are carried out in any order at all, unless the context or the details of the described operation clearly indicates otherwise.

[0041] Of course, the present disclosure may be carried out in other specific ways than those herein set forth without departing from the scope and essential characteristics of the invention. One or more of the specific processes discussed above may be carried out in a cellular phone or other communications transceiver comprising one or more appropriately configured processing circuits, which may in some embodiments be embodied in one or more application-specific integrated circuits (ASICs). In some embodiments, these processing circuits may comprise one or more microprocessors, microcontrollers, and/or digital signal processors programmed with appropriate software and/or firmware to carry out one or more of the operations described above, or variants thereof. In some embodiments, these processing circuits may comprise customized hardware to carry out one or more of the functions described above. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

[0042] Although multiple embodiments of the present invention have been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it should be understood that the invention is not limited to the disclosed embodiments, but instead is also capable of numerous rearrangements, modifications and substitutions without departing from the present invention that as has been set forth and defined within the following claims.

Claims

1. A wireless device (1041, 1042, 1043...104n) configured with a discontinuous reception (DRX) cycle (400) which comprises a reachability cycle (402), a sleep cycle (404), and a synchronization cycle (406), the wireless device comprising:

   a processor (1181, 1182, 1183...118n); and
   a memory (1201, 1202, 1203...120n) that stores processor-executable instructions, wherein the processor interfaces with the memory to execute the processor-executable instructions, whereby said wireless device is operable to:

   compute (202, 504), during the reachability cycle, a time (T_w) for the synchronization cycle during which a synchronization procedure (201) is to be performed; and

   set (204, 504) a timer with a time (T_d) based on the computed time (T_w) to wake up from the sleep cycle and perform the synchronization procedure,

   wherein the reachability cycle occurs before the sleep cycle, and the sleep cycle occurs before the synchronization cycle; and

   the wireless device is characterized to compute the time (T_w) for the synchronization cycle as follows:

   estimate (202a, 504a) a total accumulated frequency drift of the sleep cycle, wherein the total accumulated frequency drift is equal to Δf*T_S, wherein Δf is a frequency drift per unit time of a local oscillator (205) in the wireless device, and wherein T_S is an estimated duration of the sleep cycle;

   compute (202b, 504b) a number of Frequency Correction Bursts (FBs), Synchronization Bursts (SBs), and Normal Bursts (NBs) to be received to enable a correction of the estimated total accumulated frequency drift; and

   compute (202c, 504c) the time (T_w) for the synchronization cycle based on (i) a known frame structure which indicates how many FBs, SBs, and NBs are expected during a certain period of time, (ii) a known amount of frequency drift that can be corrected from each reception of FB, SB, and NB, and (iii) the computed number of FBs, SBs, and NBs to be received to enable the correction of the estimated total accumulated frequency drift.

2. The wireless device of claim 1, wherein the wireless device is further operable to:

   wake up (206, 512) one or more times during the sleep cycle to perform one or more intermediate synchronization procedures (203) when the estimated total accumulated frequency drift exceeds a threshold.

3. The wireless device of claim 2, wherein the wireless device is further operable to:

   determine (206a) when to perform each of the one or more intermediate synchronization procedures based on a mobility of the wireless device.

4. The wireless device of claim 1, wherein the wireless device is further operable to perform the synchronization procedure, which includes being operable to:

   synchronize (204a) a frequency and a time with a camped cell.

5. The wireless device of claim 4, wherein the wireless
device is further operable to perform the synchronization procedure, which includes being operable to: determine (204b) if the wireless device is receiving a signal associated with a previously camped cell or a new camped cell by checking a Training Sequence Code (TSC) indicated by a Base Station Identification Code (BSIC) of a Synchronization Burst (SB) or by checking a TSC in any received Normal Burst (NB).

6. The wireless device of claim 5, wherein the wireless device is further operable to perform the synchronization procedure, which includes being operable to:

receive (204c) in-phase and quadrature (I, Q) samples;
estimate (204d) a Received Signal Strength Indicator (RSSI) value using the received in-phase and quadrature (I, Q) samples;
verify (204e) if a C1/C2 criterion is fulfilled using the estimated RSSI value;
and
schedule (204f) a Common Control Channel (CCCH) reading or a Routing Area Update (RAU) if the C1/C2 criterion is fulfilled.

7. A method (200, 500) in a wireless device (1041, 1042, 1043...104n) configured with a discontinuous reception (DRX) cycle (400) which comprises a reachability cycle (402), a sleep cycle (404), and a synchronization cycle (406), the method comprising:

computing (202, 504), during the reachability cycle, a time \( T_W \) for the synchronization cycle during which a synchronization procedure (201) is to be performed; and
setting (204, 504) a timer with a time \( T_d \) based on the computed time \( T_W \) to wake up from the sleep cycle and perform the synchronization procedure,
wherein the reachability cycle occurs before the sleep cycle, and the sleep cycle occurs before the synchronization cycle; and
the method is characterized in that the computing the time \( T_W \) for the synchronization cycle further comprises:

estimating (202a, 504a) a total accumulated frequency drift of the sleep cycle, wherein the total accumulated frequency drift is equal to \( \Delta f \cdot T_S \), wherein \( \Delta f \) is a frequency drift per unit time of a local oscillator (205) in the wireless device, and wherein \( T_S \) is an estimated duration of the sleep cycle;
computing (202b, 504b) a number of Frequency Correction Bursts (FBs), Synchronization Bursts (SBs), and Normal Bursts (NBs) to be received to enable a correction of the estimated total accumulated frequency drift; and
computing (202c, 504c) the time \( T_W \) for the synchronization cycle based on (i) a known frame structure which indicates how many FBs, SBs, and NBs are expected during a certain period of time, (ii) a known amount of frequency drift that can be corrected from each reception of FB, SB, and NB, and (iii) the computed number of FBs, SBs, and NBs to be received to enable the correction of the estimated total accumulated frequency drift.

8. The method of claim 7, further comprising:
waking up (206, 512) one or more times during the sleep cycle to perform one or more intermediate synchronization procedures (203) when the estimated total accumulated frequency drift exceeds a threshold.

9. The wireless device of claim 8, further comprising:
determining (206a) when to perform each of the one or more intermediate synchronization procedures based on a mobility of the wireless device.

10. The method of claim 7, wherein the synchronization procedure comprises:
synchronizing (204a) a frequency and a time with a camped cell.

11. The method of claim 10, wherein the synchronization procedure further comprises:
determining (204b) if the wireless device is receiving a signal associated with a previously camped cell or a new camped cell by checking a Training Sequence Code (TSC) indicated by a Base Station Identification Code (BSIC) of a Synchronization Burst (SB) or by checking a TSC in any received Normal Burst (NB).

12. The method of claim 11, wherein the synchronization procedure further comprises:

receiving (204c) in-phase and quadrature (I, Q) samples;
estimating (204d) a Received Signal Strength Indicator (RSSI) value using the received in-phase and quadrature (I, Q) samples;
verifying (204e) if a C1/C2 criterion is fulfilled using the estimated RSSI value;
and
scheduling (204f) a Common Control Channel (CCCH) reading or a Routing Area Update (RAU) if the C1/C2 criterion is fulfilled.
Patentansprüche

1. Drahtlose Vorrichtung (1041, 1042, 1043...104n), die mit einem diskontinuierlichen Empfangs (DRX-)Zyklus (400) konfiguriert ist, der einen Erreichbarkeitszyklus (402), einen Schlafzyklus (404) und einen Synchronisierungszyklus (406) umfasst, wobei die drahtlose Vorrichtung umfasst:

- einen Prozessor (1181, 1182, 1183...118n); und
- einen Speicher (1201, 1202, 1203...120n), der auf einem Prozessor ausführbare Befehle speichert, wobei der Prozessor über eine Schnittstelle mit dem Speicher verbunden ist, um die auf einem Prozessor ausführbaren Befehle auszuführen, wodurch die drahtlose Vorrichtung ausgelegt ist zum:

- Berechnen (202, 504) während des Erreichbarkeitszyklus einer Zeit (Tw) für den Synchronisierungszyklus, während der ein Synchronisierungsvorgang (201) durchgeführt werden soll; und
- Einstellen (204, 504) eines Zeitgebers mit einer Zeit (Td) basierend auf der berechneten Zeit (Tw) zum Aufwachen aus dem Schlafzyklus und Durchführen des Synchronisierungsvorgangs, wobei der Erreichbarkeitszyklus vor dem Schlafzyklus stattfindet, und der Schlafzyklus vor dem Synchronisierungszyklus stattfindet, die drahtlose Vorrichtung dadurch gekennzeichnet ist, dass sie die Zeit (Tw) für den Synchronisierungszyklus berechnet, wie folgt:

  Schätzen (202a, 504a) einer akkumulierten Gesamtgeschwindigkeit des Schlafzyklus, wobei die akkumulierte Gesamtgeschwindigkeit \( f^*T_s \) entspricht, wobei \( f \) eine Geschwindigkeit pro Zeitanteil eines Empfangsoszillators (205) in der drahtlosen Vorrichtung ist, und wobei \( T_s \) eine geschätzte Dauer des Schlafzyklus ist;

  Berechnen (202b, 504b) einer Anzahl von Frequenzkorrekturbursts (FBs), Synchronisierungsbursts (SBs) und normalen Bursts (NBs), die empfangen werden sollen, um eine Korrektur der geschätzten akkumulierten Geschwindigkeit zu ermöglichen; und

  Berechnen (202c, 504c) der Zeit (Tw) für den Synchronisierungszyklus basierend auf (i) einer bekannten Rahmenstruktur, die angibt, wie viele FBs, SBs und NBs während eines bestimmten Zeitraums erwartet werden, (ii) einem bekannten Maß an Geschwindigkeit, das aus jedem Empfang von FB, SB und NB korrigiert werden kann, und (iii) der berechneten Anzahl von FBs, SBs und NBs, die empfangen werden sollen, um die Korrektur der geschätzten akkumulierten Gesamtgeschwindigkeit zu ermöglichen.

2. Drahtlose Vorrichtung nach Anspruch 1, wobei die drahtlose Vorrichtung ferner ausgelegt ist zum: ein- oder mehrmaligen Aufwachen (206, 512) während des Schlafzyklus, um einen oder mehrere Zwischensynchronisierungsvorgänge durchzuführen (203), wenn die geschätzte akkumulierte Gesamtgeschwindigkeit eine Schwelle überschreitet.

3. Drahtlose Vorrichtung nach Anspruch 2, wobei die drahtlose Vorrichtung ferner ausgelegt ist zum: Bestimmen (206a), wann jeder der einen oder der mehreren Zwischensynchronisierungsvorgänge durchgeführt werden soll, basierend auf einer Mobilität der drahtlosen Vorrichtung.

4. Drahtlose Vorrichtung nach Anspruch 1, wobei die drahtlose Vorrichtung ferner zum Durchführen des Synchronisierungsvorgangs ausgelegt ist, was umfasst, dass sie ausgelegt ist zum: Synchronisieren (204a) einer Frequenz und einer Zeit bei einer wartenden Zelle.

5. Drahtlose Vorrichtung nach Anspruch 4, wobei die drahtlose Vorrichtung ferner zum Durchführen des Synchronisierungsvorgangs ausgelegt ist, was umfasst, dass sie ausgelegt ist zum: Bestimmen (204b), ob das Signal empfangen, das mit einer früheren wartenden Zelle oder einer neuen wartenden Zelle assoziiert ist, durch Prüfen eines Trainingsequenzcodes (TSC), der durch einen Basistationsidentifikationscode (BSIC) eines Synchronisierungsbursts (SB) angegeben wird, oder durch Prüfen eines TSCs in einem beliebigen empfangenen normalen Burst (NB).

6. Drahtlose Vorrichtung nach Anspruch 5, wobei die drahtlose Vorrichtung ferner zum Durchführen des Synchronisierungsvorgangs ausgelegt ist, was umfasst, dass sie ausgelegt ist zum:

- Empfangen (204c) von Inphase- und Quadratur (I, Q)-Abtastwerten;
- Schätzen (204d) eines Empfangssignalstärkeindikators (RSSI)-Wertes unter Verwendung der empfangenen Inphase- und Quadratur (I, Q)-Abtastwerte;
- Verifizieren (204e), ob ein C1/C2-Kriterium erfüllt wird, unter Verwendung des geschätzten RSSI-Werts; und
- Disponieren (204f) von CCCH (gemeinsamer Steuerkanal)-Lesung oder Aufenthaltsgebietaktualisierung (RAU), wenn das C1/C2-Kriteri...
um erfüllt wird.

7. Verfahren (200, 500) in einer drahtlosen Vorrichtung (104₁, 104₂, 104₃...104ₙ), die mit einem diskontinuierlichen Empfangs (DRX)-Zyklus (400) konfiguriert ist, der einen Erreichbarkeitszyklus (402), einen Schlafzyklus (404) und einen Synchronisierungszyklus (406) umfasst, wobei das Verfahren umfasst:

Berechnen (202, 504) während des Erreichbarkeitszyklus einer Zeit (T_w) für den Synchronisationszyklus, während der ein Synchronisierungszyklus (201) durchgeführt werden soll; und

Einstellen (204, 504) eines Zeitgebers mit einer Zeit (T_d) basierend auf der berechneten Zeit (T_w) zum Aufwachen aus dem Schlafzyklus und Durchführen des Synchronisierungszyklus, wobei der Erreichbarkeitszyklus vor dem Schlafzyklus stattfindet, und der Schlafzyklus vor dem Synchronisierungszyklus stattfindet; und das Verfahren dadurch gekennzeichnet ist, dass das Berechnen der Zeit (T_w) für den Synchronisierungszyklus ferner umfasst:

Schätzen (202a, 504a) einer akkumulierten Gesamtfrequenzdrift des Schlafzyklus, wobei die akkumulierte Gesamtfrequenzdrift Δf*Ts entspricht, wobei Δf eine Frequenzdrift pro Zeiteinheit eines Empfangsschalters (205) in der drahtlosen Vorrichtung ist, und wobei T_s eine geschätzte Dauer des Schlafzyklus ist;

Berechnen (202b, 504b) einer Anzahl von Frequenzenkorrekturbursts (FBs), Synchronisierungsbursts (SBs) und normalen Bursts (NBs), die empfangen werden soll, um eine Korrektur der geschätzten akkumulierten Frequenzdrift zu ermöglichen; und

Berechnen (202c, 504c) der Zeit (T_w) für den Synchronisierungszyklus basierend auf (i) einer bekannten Rahmenstruktur, die angibt, wie viele FBs, SBs und NBs während eines bestimmten Zeitraums erwartet werden, (ii) einem bekannten Maß an Frequentzdrift, das aus jedem Empfang von FB, SB und NB korrigiert werden kann, und (iii) der berechneten Anzahl von FBs, SBs und NBs, die empfangen werden soll, um die Korrektur der geschätzten akkumulierten Gesamtfrequenzdrift zu ermöglichen.

8. Verfahren nach Anspruch 7, ferner umfassend: ein- oder mehrmaliges Aufwachen (206, 512) während des Schlafzyklus, um einen oder mehrere Synchronisierungszyklen durchzuführen (203), wenn die geschätzte akkumulierte Gesamtfrequenzdrift eine Schwelle überschreitet.

9. Verfahren nach Anspruch 8, ferner umfassend: Bestimmen (206a), wann jeder des einen oder der mehreren Zwischensynchronisierungsvorgänge durchgeführt werden soll, basierend auf einer Mobilität der drahtlosen Vorrichtung.

10. Verfahren nach Anspruch 7, wobei der Synchronisierungszyklus ferner umfasst: Synchronisieren (204a) einer Frequenz und einer Zeit bei einer wartenden Zelle.

11. Verfahren nach Anspruch 10, wobei der Synchronisierungszyklus ferner umfasst: Bestimmen (204b), ob die drahtlose Vorrichtung ein Signal empfängt, das mit einer früheren wartenden Zelle oder einer neuen wartenden Zelle assoziiert ist, durch Prüfen eines Trainingssequenzcodes (TSC), der durch einen Basisstationsidentifikationscode (BSIC) eines Synchronisierungsbursts (SB) angegeben wird, oder durch Prüfen eines TSCs in einem beliebigen empfangenen normalen Burst (NB).

12. Verfahren nach Anspruch 11, wobei der Synchronisierungszyklus ferner umfasst:

Empfangen (204c) von Inphase- und Quadratur (I, Q)-Abtastwerten;
Schätzen (204d) eines Empfangssignalstärkeindikators (RSSI)-Wertes unter Verwendung der empfangenen Inphase- und Quadratur (I, Q)-Abtastwerte;
Verifizieren (204e), ob ein C1/C2-Kriterium erfüllt wird, unter Verwendung des geschätzten RSSI-Werts; und Disponieren (204f) von CCCH (gemeinsamer Steuerkanal)-Lesung oder Aufenthaltsgebietaktualisierung (RAU), wenn das C1/C2-Kriterium erfüllt wird.

Revendications

1. Dispositif sans fil (104₁, 104₂, 104₃...104ₙ) configuré avec un cycle de réception discontinue (DRX) (400) qui comprend un cycle d’accessibilité (402), un cycle de veille (404), et un cycle de synchronisation (406), le dispositif sans fil comprenant :

un processeur (118₁, 118₂, 118₃ ... 118ₙ); et
une mémoire (120₁, 120₂, 120₃ ... 120ₙ) qui mémore des instructions exécutables par processeur, dans lequel le processeur est en interface avec la mémoire pour exécuter les instructions exécutables par processeur, de telle manière que ledit dispositif sans fil soit utilisable pour effectuer :
le calcul (202, 504), au cours du cycle d’accessibilité, d’un temps \(T_W\) pour le cycle de synchronisation au cours duquel une procédure de synchronisation (201) doit être effectuée ; et le réglage (204, 504) d’une minuterie avec un temps \(T_d\) sur la base du temps calculé \(T_W\) pour le réveil du cycle de veille et pour effectuer la procédure de synchronisation, dans lequel le cycle d’accessibilité se déroule avant le cycle de veille, et le cycle de veille se déroule avant le cycle de synchronisation ; et le dispositif sans fil est caractérisé en ce qu’il calcule le temps \(T_W\) pour le cycle de synchronisation en effectuant :

- l’estimation (202a, 504a) d’une dérive de fréquence cumulée totale du cycle de veille, dans lequel la dérive de fréquence cumulée totale est égale à \(\Delta f \times T_S\), où \(\Delta f\) est une dérive de fréquence par unité de temps d’un oscillateur local (205) dans le dispositif sans fil, et \(T_S\) est une durée estimée du cycle de veille ;
- le calcul (202b, 504b) d’un nombre de rafales de correction de fréquence (FB), de rafales de synchronisation (SB) et de rafales normales (NB) à recevoir pour permettre une correction de la dérive de fréquence cumulée totale estimée ; et
- le calcul (202c, 504c) du temps \(T_W\) pour le cycle de synchronisation sur la base de (i) une structure de trame connue qui indique combien de FB, SB et NB sont prévues au cours d’une certaine période de temps, (ii) une quantité connue de dérive de fréquence pouvant être corrigée à partir de chaque réception de FB, SB et NB, et (iii) le nombre calculé de FB, SB et NB à recevoir pour permettre la correction de la dérive de fréquence cumulée totale estimée.

2. Dispositif sans fil selon la revendication 1, dans lequel le dispositif sans fil est en outre utilisable pour effectuer :

le réveil (206, 512) une ou plusieurs fois pendant le cycle de veille pour effectuer une ou plusieurs procédures de synchronisation intermédiaires (203) lorsque la dérive de fréquence cumulée totale estimée dépasse un seuil.

3. Dispositif sans fil selon la revendication 2, dans lequel le dispositif sans fil est en outre utilisable pour effectuer :

la détermination (206a) quand effectuer chacune de l’une ou plusieurs procédures de synchronisation intermédiaires sur la base d’une mobilité du dispositif sans fil.

4. Dispositif sans fil selon la revendication 1, dans lequel le dispositif sans fil est en outre utilisable pour effectuer la procédure de synchronisation comprenant :

- la synchronisation (204a) d’une fréquence et d’un temps avec une cellule de localisation.

5. Dispositif sans fil selon la revendication 1, dans lequel le dispositif sans fil est en outre utilisable pour effectuer la procédure de synchronisation comprenant :

- la détermination (204b) si le dispositif sans fil reçoit un signal associé à une cellule de localisation précédente ou à une nouvelle cellule de localisation par le contrôle d’un code de séquence de formation (TSC) indiqué par un code d’identification de station de base (BSIC) d’une rafale de synchronisation (SB) ou par le contrôle d’un TSC dans n’importe quelle rafale normale (NB) reçue.

6. Dispositif sans fil selon la revendication 5, dans lequel le dispositif sans fil est en outre utilisable pour effectuer la procédure de synchronisation comprenant :

- la réception (204c) d’échantillons en phase et en quadrature (I, Q) ;
- l’estimation (204d) d’une valeur d’indicateur de force de signal reçu (RSSI) en utilisant les échantillons en phase et en quadrature (I, Q) reçus ;
- la vérification (204e) si un critère C1/C2 est rempli en utilisant la valeur RSSI estimée ; et
- la programmation (204f) d’un relevé de canal de commande commun (CCCH) ou d’une mise à jour de zone d’acheminement (RAU) si le critère C1/C2 est rempli.

7. Procédé (200, 500) dans un dispositif sans fil (1041, 1042, 1043 ... 104n) configuré avec un cycle de réception discontinue (DRX) (400) qui comprend un cycle d’accessibilité (402), un cycle de veille (404), et un cycle de synchronisation (406), le procédé comprenant :

- le calcul (202, 504), au cours du cycle d’accessibilité, d’un temps \(T_W\) pour le cycle de synchronisation au cours duquel une procédure de synchronisation (201) doit être effectuée ; et
- le réglage (204, 504) d’une minuterie avec un temps \(T_d\) sur la base du temps calculé \(T_W\) pour le réveil du cycle de veille et pour effectuer la procédure de synchronisation, dans lequel le cycle d’accessibilité se déroule avant le cycle de veille, et le cycle de veille se déroule avant le cycle de synchronisation ; et...
le procédé est caractérisé en ce que le calcul du temps \( T_W \) pour le cycle de synchronisation comprend en outre :

l’estimation (202a, 504a) d’une dérive de fréquence cumulée totale du cycle de veille, dans lequel la dérive de fréquence cumulée totale est égale à \( \Delta^f T_S \), où \( \Delta^f \) est une dérive de fréquence par unité de temps d’un oscillateur local (205) dans le dispositif sans fil, et \( T_S \) est une durée estimée du cycle de veille ;

le calcul (202b, 504b) d’un nombre de rafales de correction de fréquence (FB), de rafales de synchronisation (SB) et de rafales normales (NB) à recevoir pour permettre une correction de la dérive de fréquence cumulée totale estimée ; et

le calcul (202c, 504c) du temps \( T_W \) pour le cycle de synchronisation sur la base de (i) une structure de trame connue qui indique combien de FB, SB et NB sont prévues au cours d’une certaine période de temps, (ii) une quantité connue de dérive de fréquence pouvant être corrigée à partir de chaque réception de FB, SB et NB, et (iii) le nombre calculé de FB, SB et NB à recevoir pour permettre la correction de la dérive de fréquence cumulée totale estimée.

8. Procédé selon la revendication 7, comprenant en outre :
le réveil (206, 512) une ou plusieurs fois pendant le cycle de veille pour effectuer une ou plusieurs procédures de synchronisation intermédiaires (203) lorsque la dérive de fréquence cumulée totale estimée dépasse un seuil.

9. Procédé selon la revendication 8, comprenant en outre :
la détermination (206a) quand effectuer chacune de l’une ou plusieurs procédures de synchronisation intermédiaires (203) lorsque d’une mobilité du dispositif sans fil.

10. Procédé selon la revendication 7, dans lequel la procédure de synchronisation comprend :
là synchronisation (204a) d’une fréquence et d’un temps avec une cellule de localisation.

11. Procédé selon la revendication 10, dans lequel la procédure de synchronisation comprend en outre :
là détermination (204b) si le dispositif sans fil reçoit un signal associé à une cellule de localisation précédente ou à une nouvelle cellule de localisation par le contrôle d’un code de séquence de formation (TSC) indiqué par un code d’identification de station de base (BSIC) d’une rafale de synchronisation (SB) ou par le contrôle d’un TSC dans n’importe quelle rafale normale (NB) reçue.

12. Procédé selon la revendication 11, dans lequel la procédure de synchronisation comprend en outre :
la réception (204c) d’échantillons en phase et en quadrature (I, Q) :
là estimation (204d) d’une valeur d’indicateur de force de signal reçu (RSSI) en utilisant les échantillons en phase et en quadrature (I, Q) reçus ;
là vérification (204e) si un critère C1/C2 est rempli en utilisant la valeur RSSI estimée ; et
la programmation (204f) d’un relevé de canal de commande commun (CCCH) ou d’une mise à jour de zone d’acheminement (RAU) si le critère C1/C2 est rempli.
FIG. 2

1. **Compute** $T_w$ of synchronization cycle
   - Estimate Accumulated _FO_over_sleep
   - Compute number of FBs, SBs and NBs to be received to enable a correction of estimated Accumulated _FO_over_sleep
   - Compute $T_w$ based on (i) known frame structure indicates how many FBs, SBs, and NBs are expected during a time period, (ii) known amount of frequency drift that can be corrected from each reception of FB, SB, and NB and (iii) computed number of FBs, SBs, and NBs to be received to enable correction of estimated Accumulated _FO_over_sleep

2. **Set a timer** with $T_d$ based on computed $T_w$ to wake-up from sleep cycle and perform synchronization procedure (201)
   - The synchronization procedure (201) comprises
     - Synchronize frequency and time with camped cell
     - Determine if receivable signal from previously camped cell or new camped cell
     - Receive I,Q samples
     - Estimate RSSI
     - Verify if C1/C2 is fulfilled
     - Schedule CCCH reading or RAU

3. **Wake-up one or more times in sleep cycle to perform intermediate synchronization procedure** (203) if Accumulated _FO_over_sleep > X
   - Determine when to perform intermediate synchronization procedure based on mobility of wireless device
FIG. 5A

THE WIRELESS DEVICE IS CONFIGURED WITH A DRX CYCLE LENGTH = T_L, WHICH MEANS THE WIRELESS DEVICE SHOULD RECEIVE THE CCCH BLOCK'S FIRST BURST (i.e., THE FIRST BURST OF ITS NOMINAL PAGING BLOCK) AT THE START OF EVERY T_L TIME PERIOD.

BEFORE GOING TO SLEEP, THE WIRELESS DEVICE SETS A TIMER WITH T_d TO WAKE UP T_W AHEAD OF THE START OF THE NEXT DRX CYCLE (i.e., THE VALUE OF T_d DETERMINES THE LENGTH OF THE SLEEP DURATION, T_s). T_s IS COMPUTED DYNAMICALLY BASED ON THE LENGTH OF T_w COMPUTED. T_w IS COMPUTED BASED ON:

1. COMPUTED LINEAR DRIFT OF LOCAL OSCILLATOR (LO) OVER THE ESTIMATED WIRELESS DEVICE SLEEP DURATION: \( \Delta f \cdot T_s = \text{accumulated}\_\text{FO}\_\text{over}\_\text{sleee} \)

2. COMPUTED NUMBER OF FB (N1), SB (N2), NB (N3) TO BE RECEIVED TO ENABLE A CORRECTION OF ESTIMATED Accumulated\_FO\_over\_sleep

3. DYNAMICALLY COMPUTE T_w FOR SYNCHRONIZATION CYCLE BASED ON:
   - ESTIMATED Accumulated\_FO\_over\_sleep
   - COMPUTED NUMBER OF FBs, SBs, AND NBs TO BE RECEIVED TO ENABLE A CORRECTION OF ESTIMATED Accumulated\_FO\_over\_sleep
   - COMPUTED T_w BASED ON (i) KNOWN FRAME STRUCTURE INDICATES HOW MANY FBs, SBs, AND NBs ARE EXPECTED DURING A TIME PERIOD, (ii) KNOWN AMOUNT OF FREQUENCY DRIFT THAT CAN BE CORRECTED FROM EACH RECEIPTION OF FB, SB, AND NB AND (iii) COMPUTED NUMBER OF FBs, SBs, AND NBs TO BE RECEIVED TO ENABLE A CORRECTION OF ESTIMATED Accumulated\_FO\_over\_sleep

IF (accumulated\_FO\_over\_sleep > X)?

NO

YES

506

A

TO FIG. 5B

B

TO FIG. 5B
FROM FIG. 5A

A

INTERMEDIATE SYNCHRONIZATION PROCEDURE (203) BEFORE $T_w$ IS NEEDED, i.e., INTERMEDIATE SYNCHRONIZATION PROCEDURE (203) BEFORE THE END OF $T_s$ IS NEEDED

B

COMPUTE THE TIME ($T_{int}$) WHEN FB OR SB WILL BE APPEARING IN THE TDMA FRAME STRUCTURE. [$T_{int} < T_d$]

WAKE UP AT $T_{int}$ AND RECEIVE FB OR SB AS SCHEDULED AND SYNCHRONIZE AND THEN GO TO SLEEP AGAIN AFTER ESTIMATING THE NEXT WAKE UP INSTANT

INTERMEDIATE SYNCHRONIZATION PROCEDURE (203) BEFORE $T_w$ IS NOT NEEDED, i.e., INTERMEDIATE SYNCHRONIZATION PROCEDURE (203) BEFORE THE END OF $T_s$ IS NOT NEEDED

WAKE UP TIME BEFORE $T_L$, WHERE $T_L - T_w - T_R = T_s$ AND PERFORM THE SYNCHRONIZATION PROCEDURE (201) FOR DURATION OF $T_w$ BEFORE CCCH RECEPTION

FIG. 5B
IF THE ACCUMULATED FO IS GREATER THAN THRESHOLD, THEN THE WIRELESS DEVICE WAKES UP AT T_{\text{INT}} DURING T_s FOR ONE (SHOWN) OR MORE TIMES (NOT SHOWN) TO RECEIVE FB OR SB AND PERFORM INTERMEDIATE SHORT SYNCUP TO AVOID LONG SYNC AT T_d. T_{\text{INT}} IS THE INTERMEDIATE TIME INSTANT WHEN THE WIRELESS DEVICE WAKES UP FOR FB OR SB RECEPTION.

FIG. 6
N1 NUMBER OF FBs, N2 NUMBER OF SBs, AND N3 NUMBER OF NBs WILL BE APPEARING IN $T_W$ TIME WINDOW. $T_W = N*577 \mu s = (N1+N2+N3)*577 \mu s$

$T_R$ $T_S$ $T_W$ $T_R$ $T_S$ $T_W$

$T_L = \text{DRX CYCLE LENGTH}$

(WIRELESS DEVICE WILL BE RECEIVING CCCH BLOCK EVERY $T_L$ INTERVAL)

FIG. 7
REFERENCES CITED IN THE DESCRIPTION

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