Proxying Location Update for Idle Mode Interfaces

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ABSTRACT
In cellular networks it is the mobile node’s responsibility to update the network about its location change, especially when this one enters idle mode. We developed a new framework [8] where the idle interface is powered-off to save energy and thus could neither detect its location change nor perform a location update. This framework uses a proxy entity at the network and at the mobile node the active radio interface for proxying the idle interface. In this paper, we present an approach that relies on the proxy entity and the active interface for proxying the location update procedure of the proxied interfaces. More specifically, we propose two algorithms. The first algorithm considers proxying periodic location update of idle interface without considering its mobility if there is any. The second algorithm is based on sending the location to the Information Server which determines the list of paging/tracking areas that serves the current location. We present the design of our architecture for 4G systems, namely WiMAX and LTE. The algorithms are analytically evaluated to evaluate the power savings compared with single-radio power management.

Categories and Subject Descriptors
C.5.3 [Computer System Implementation]: Microcomputers - Portable devices

General Terms
Algorithms, Management, Performance, Design, Standardization.

Keywords
Location-Update; Proxied Multi-Radio Interface; Idle/Active mode; Proxy entity; Proxied interface; MIH services.

1. INTRODUCTION
Multi-radio devices provide end-users the ability to achieve ubiquitous and seamless connectivity anytime, anywhere across heterogeneous wireless networks (e.g., Wi-Fi, WiMAX, LTE); however, these radios consume large amounts of energy. The utility of the devices is directly impacted by the longevity of their operation before batteries need to be replaced or recharged. Thus, the challenge is to design multi-radio devices that use energy efficiently; the objective is to provide the benefits of using multiple radios with low energy consumption.

In existing systems, the power management of each radio interface of a multi-radio device (the mobile node) is managed individually by its corresponding network technology. For example, each idle radio interface of the mobile node (MN) has to perform a location update individually with its corresponding network entity. In fact, each idle interface of the MN has to be available for a certain amount of time (this depends on the network policy) to be able to receive data from its network and react accordingly. This is how a network informs the idle interface (through paging procedure) about a pending call/data if there is any. The concerned interface (by this call/data) has to switch to active mode to be able to receive the call/data.

Actually, it is the location update procedure, performed by the idle interfaces with their corresponding network entities (e.g. PC (Paging Controller) in WiMAX [3] or MME (Mobility Management Entity) in 3GPP LTE [4]) that allows the network to be updated about the location of the managed interfaces at paging/tracking area granularity. To page an idle MN, the network broadcasts a paging message in paging/tracking area(s) where the network believes the MN is currently located. In [8], we proposed the IMIP (Integrated Management of Interface Power consumption) framework [8] which is built as an extension of the IEEE 802.21 Media Independent Handover (MIH) standard [6]; the proposed extension concerns mainly the MIH services, their primitives and a new functional network entity called proxy (co-located with the PoS (Point of Service) [8]).

In this paper, we propose an extension of IMIP to support a new function namely the location update (or proxied location update). The rest of this paper is organized as follows. Section II briefly presents the IMIP framework and then the location update procedure in WiMAX and 3GPP LTE systems. Section III describes the proposed proxying location update mechanism in IMIP. Section IV presents the implementation details used for the communication between the proxy and the PC/MMME. Section V evaluates the performance of proxying idle radio interfaces (WiMAX and 3GPP) and location update procedure. Finally, section VI concludes the paper.

2. IMIP Framework for Location Update
In this section, we briefly introduce IMIP framework (see [8] for more details); in this paper, we propose an extension of IMIP that concerns location update in 4G networks; thus, an overview of location update mechanisms in WiMAX [3, 6] and 3GPP LTE [4, 7] systems is presented.

2.1 IMIP Framework
In [8], we proposed a framework, called IMIP, for an effective power management of a multi-radio MN. The framework considers the power management of mobile devices from a global view; this is in opposition to existing single radio power management provided by each wireless standard. The best way to save energy is to power-off an interface when it is idle and to use a proxy network entity (in its corresponding network) for each powered-off interface.

Fig. 1 shows a heterogeneous network composed of 3 different networks (WiMAX, Wi-Fi and 3GPP LTE) and a mobile node with 3 interfaces. Two of these interfaces (WiMAX and 3GPP LTE) are in power-off state and the third one is in active state (Wi-Fi). Each powered-off interface is proxied on its network by...
the corresponding proxy entity; the active interface is used to maintain the signaling sessions between proxies and Network Selection Entity (NSE) on the MN [8]. For each proxied interface, the NSE entity (on the MN) maintains an IP session, called NSE session (Fig. 1-2), with the proxy. It allows EMIH (Enhanced MIH) [8] message exchanges between NSE and proxy entities. This is how the proxy sends and receives requests (commands, events information) to/from the MN concerning the proxied interface. Thus, when an idle interface is proxied, it is the proxy that becomes responsible for the functions (i.e., performs the functions) intended for the interface.

2.2 Location update in WiMAX

With location update procedure, to save battery power on the handset device (MN), the WiMAX radio interface goes into idle mode when it is not involved in an active session. To alert the mobile, in this case, about an incoming message, WiMAX network makes use of its paging system. The WiMAX paging reference model decomposes the paging function into three separate functional entities: PC (Paging Controller), PA (Paging Agent) and Location Register [3].

The PC is a functional entity that manages the activity of idle interface in the network. The PC is identified by PC_ID and may be co-located with the base station. WiMAX system requires that each idle interface to be managed by a single PC which is referred to as anchor PC. The latter manages and maintains the location information of more than one idle interface and could manage more than one paging area. For different reasons (e.g. user mobility) the idle interface could be assigned a new anchor PC which becomes its managing entity. This is referred to as PC relocation; it happens mainly during a location update procedure.

The PA is a BS functional entity that handles the interaction between the PC and the BS paging-related functions. A set of PAs/BSs form a PG (paging group or paging area).

According to [10], there are four location update conditions which trigger the MS (Mobile Station) in idle mode to perform a LU (Location Update). Among these conditions: (1) ‘Paging Group Update’: this is when the mobile detects a change in the paging area; and (2) ‘Timer Update’: where the MS shall periodically perform Location Update prior to the expiration of the ‘Idle Mode Timer’. The latter defines time interval between two LUs.

2.3 Tracking area update in LTE

In 3GPP LTE system [4], when a radio interface is in idle mode, the location of the mobile is known by the MME and only at the granularity of a Tracking Area (TA) which consists of multiple eNBs (evolved NodeBs). The MME manages one or more TAs, and keeps the list of TAs sent to each mobile where no TAU (Tracking Area Update) is required as long as the mobiles are located in these TAs. If the mobile gets in a TA which is not in the TAL (Tracking Area List) sent by the MME, it has to perform a TAU (Tracking Area Update) with the MME informing it about its new location. For different reasons (e.g. user mobility, MME load balancing) the mobile could change the serving MME to become managed by a different MME [11]. This is referred to as MME change or relocation. To locate the mobile to a cell granularity, paging is necessary.

The tracking area update procedure performs two types of tracking update [5]: (1) normal tracking area update and its objective is to update the registration of the actual tracking area of the mobile in the network; and (2) periodic tracking area update which is controlled by timer T3412 [4], this used by the mobile to notify periodically the network about his availability (or presence).

In summary, for both systems (WiMAX, 3GPP LTE) presented here, there are mainly two situations where a LU is performed: (1) periodically where the MN maintains ‘LU timer’ and after its expiration it should perform a LU. Otherwise, the mobile may get considered out of the network and the allocated resources in the system will be released; and (2) when the MN changes the tracking/paging (location) area.

3. Proxying Location Update

The following section presents the proxying LU mechanism according to IMIP framework; more specifically, we are concerned with WiMAX and 3GPP LTE systems.

3.1 Proxying radio interface

The proxy entity is an extension of PoS [8] functionality which concerns the proxied interface. The extended functionality corresponds mainly to the tasks that the proxied interface is required to perform while in idle mode. Thus, the interface can get powered-off, which allows a maximum of energy saving and thus longer MN lifespan and this without losing the connectivity state with the network. When a call arrives, the proxy sends a CS (Command Service) message (MIH-Wake-Up) [8] to the MN to wake-up the concerned proxy interface which then performs an idle mode exit.

In this paper, we present a new proxied functionality performed by the proxy on behalf of the MN. The proxied functionality is location update (a MN is required to perform while in idle/proxied mode). Fig. 1 presents a MN with multiple radio interfaces (Wi-Fi, WiMAX and 3GPP LTE) where one (Wi-Fi) is in active state and the others are proxied. It illustrates how the MN maintains NSE sessions with the proxies for the proxied interfaces (WiMAX and 3GPP LTE) through the active interface. It also shows the proxies exchanging messages, concerning the LU procedure for the proxied interfaces, with PC/MME.

3.2 Techniques for proxying LU

Recall that for networks supporting idle mode management, the idle MNs have to perform a LU/TAU procedure periodically (periodic LU). This procedure is used by the network entities (e.g. PC and MME) to maintain the managed MNs present in the network (or connected). The inconvenience of this requirement is that the idle interface has to wake-up periodically in order to perform periodic LU. Thus, the MN energy is consumed for non useful usage. Our solution to overcome this inconvenience is that the proxied interface stays powered-off and it is the proxy entity...
that performs the periodic LU on its behalf. For example, Fig. 1-2 illustrate the case of two proxied interfaces (e.g. WiMAX and 3GPP) for which their corresponding proxies are performing periodic LU for them.

Fig. 2 shows how the proxy exchanges LU/TAU messages with the PC/MME concerning the LU procedure for the proxied interface. These technology specific messages correspond, in IEEE 802.21 standard, to a new proposed command service link primitive (Link_Location_Update) to be used by the proxy for the LU procedure with PC/MME entity. The Figure also illustrates, the PC/MME asking in their response (TAU Accept/LU_Rsp) the MN to update some of its parameters (e.g. GUTI (Globally Unique Temporary ID), TAI (Tracking Area Identity) or PC relocation indication). Upon receipt of the response (from PC/MME), the proxy updates locally the maintained parameters for the proxied interface. Then, it sends back to the MN a command service message Net_MIH_Location_Update, using NSE session (through the active interface). The MN could use these new received values to update the maintained parameters for the proxied interface and stays synchronized with its network.

In proxied multi-radio framework, proxied interfaces are not able to receive the PG/TA (Paging/Group/Tracking Area) ID broadcasted by their respective PoAs (Point of Attachment); this means that the location update (triggered by user mobility/location change) will never take place. However, the MN is required to perform a LU, to inform the network each time it gets aware that it has moved to a new area (or if the current TA not in the TAL). The LU procedure allows the system to maintain and update the information concerning the location of the MN; this helps paging the MN with reduced resources (using only PoAs that belong to paging/tracking area where the MN is currently located) and within an acceptable delay. To satisfy this requirement, the MN should be able to detect that it has changed the paging/tracking area without using the broadcasted information (e.g. Paging_ID) by the PoAs.

We propose two solutions for this problem; (1) Proxying LU procedure without considering the MN mobility (periodic LU only) and (2) Proxying LU procedure considering the MN mobility (and periodic LU).

3.2.1 Proxying LU without considering MN mobility

When the MN enters idle mode and gets proxied (powered-off) by the proxy entity, the latter starts performing the required periodic LU procedure on the MN’s behalf. During the proxying period, the MN is considered to be located on the same paging/tracking area where the MN has performed the idle mode entry (and get proxied). In this solution, the MN is considered to be located in the same location even if it has really moved to a new location/area not under the management of its PC/MME. The MN could move freely without the obligation to be aware of its ‘real’ location and to report the changes to the proxy (then to the PC/MME). Thus, during the proxying period the system believes that the MN has not changed the location. The only requirement that should be respected here is that the system should be always able to wake-up the MN when a call arrives.

In [8] we explained how the MN maintains a NSE session with the proxy during the proxying period. The session is used to exchange the extended MIH messages (extended CS (Command Service), ES (Event Service) and IS (Information Service) messages). To wake-up a proxied interface, the proxy sends a wake-up message to the MN instead of using the paging system which relies on the location information of the MN. This way the location information is not very critical to be maintained and updated in the system.

3.2.2 Proxying LU considering MN mobility

In this section, we present a solution that the MN can use to detect that it has changed the paging/tracking area. This solution uses two types of information; (1) the geo-location of the MN and (2) the geo-location of the paging/tracking areas maintained by the IS (Information Server) (refer to [2] for details about the IS server). The event that triggers the proxied interface to initiate a LU procedure is the geographic position/location change.

Fig. 3 shows how a location update is performed considering the MN mobility. The figure focuses mainly on the interaction between the MN and the IS server and the triggered functions on each entity. After idle interface enters idle mode and get proxied, here are the steps to be performed to realise a LU:

a) MN periodically checks its new geolocation and compares it with the previous one. If the difference is significant (~200 meters), then the MN has possibly changed the paging/tracking areas (of some or all proxied interfaces). The value for the periodicity check, of the mobility of the MN, and the value of the distance (triggering the MN to send a request to the IS server) depend on the radio coverage of the network of the proxied interface.

b) The MN then sends an IS (Information Service) request (MIH_Get Information) to the IS server indicating; (a) its current geographic location and (b) the list of networks the MN needs to know if there is a location change.

c) The IS server uses the geolocation of the MN to determine the paging/tracking areas (among the requested networks) that are serving this region, then, it sends the response to the MN.

d) Upon receipt of the response, the MN (MIH user layer) compares the received list with the paging/tracking areas maintained by the MN. If there is a difference, this means the MN has moved to a new location (new one in the received list) and a LU should be performed.

e) As the MN has changed the location, the proxied interface should be waked-up to perform a LU. This is initiated by the MIH user which sends a CS message (MIH_Wake-Up) to MIHF layer; to be sent to the proxied interface(s) (concerned by the location change). The CS message indicates that the proxied
interface has to perform a LU procedure (with its corresponding PC/MME).

If the new location is managed by the same serving PC/MME entity, then the location update is performed between the MN (concerned interface(s)) and that PC/MME entity; without involving the proxy. The case where the new location is managed by a different PC/MME is presented later (see PC/MME relocation section).

After performing the location update, the interface goes back to idle/proxied mode.

**PC/MME Relocation**

If the MN has moved to a new location that is managed by a different PC/MME entity, then the MN management should be relocated to different managing PC/MME entity; the relocation procedure is then performed as defined by the corresponding network [3,4]. Since the proxy is co-located with the PC/MME entity, it should be relocated too; this results in: (1) ending the NSE session with the old proxy; (2) establishing a new NSE session with a new proxy co-located with the new PC/MME entity and (3) the new proxy starts EMIH message exchanges with the new managing PC/MME (see section IV for more details). Once the LU is performed successfully, the interface could go back to idle/proxied mode without having to switch to active state.

The proposed solution here requires; (a) to extend the usage of the IS message (MIH_Get Information.request/response) to be used as request/response between the MN and IS. The extension, of this existing IS message concerns, mainly, the possibility to exchange paging/tracking areas information, of the MN’s proxied interfaces, specifically, the areas where the MN could be current located; (b) to wake-up the proxied interface after the reception of the MIH_Wake-Up and (c) the relocation (if needed) of the serving PC/MME and the proxy that might be triggered by the MN mobility.

### 4. DESIGN of IMIP FRAMEWORK FOR LU

The requirements we consider in the proposed design are: the proxy must be collocated with PC/MME and no change or minimum modification to the existing PC/MME software. Thus, we propose to add a light-weight entity, called Wrapper, to PC/MME; this entity receives/intercepts messages from the lower layers (e.g. link layer or base station) and sends a copy to the proxy entity which communicates with NSE over the active interface. Proxy and Wrapper entities communicate using inter-process communication (IPC).

#### 4.1 Wrapper Entity on MME

In LTE systems, the MME entity exchanges control messages with its managed eNodeBs through the S1-MME interface between the S1-AP (S1-Application Protocol) layers on both sides [7].

As illustrated in Fig. 4, we propose a new wrapper entity (in S1-AP layer) that will be used for communication between the MME and the proxy. The role of this entity is described in the following. To communicate with the MME, the proxy (extended MIHF layer) sends it messages to the wrapper entity which receives them and processes them like coming from the access network entities (e.g. eNodeB). Then the wrapper entity sends them to the MME.

#### 4.2 Wrapper Entity on PC

The proxy is co-located with the anchor PC on the same ASN-GW (for the three profiles A, B & C [4]); it is extended with a wrapper entity that supports IPC message (MIH CS, ES & IS primitives) exchanges with the proxy. As shown in Fig. 5, when the MS enters idle mode and gets proxied, the proxy starts performing the periodic location update with the anchor PC. A CS message (MIH_Location_Update) is sent from upper layer (MIH user) to lower layer (MIHF layer) which triggers Link_CS message (Link_Location_Update) to be sent to anchor PC. This CS message is equivalent, in WiMAX technology, to LU_Req message.

As illustrated in Fig. 4-5 the MIH user maintains a timer for each proxied interface. When the timer expires, the MIH user sends a CS message (MIH_Location_Update) to the MIHF layer. The latter processes the message and generates the corresponding specific Link_CS message (Link_Location_Update). This message corresponds to TAU_Request message in 3GPP LTE and to LU_Req message in WiMAX. The new generated specific
Link CS message (\textit{Location\_Update}) is sent to the PC/MME using the IPC communication channel. Once the PC/MME receives the CS message through the SI-AP/PC wrapper layer (it is perceived as received directly from the idle interface), the location update procedure is performed and the PC/MME updates the MN state.

\subsection*{4.3 IS and CS primitives extension}

For proxying the LU procedure, new MIH CS primitives are proposed and one existing IS primitive definition is extended. The two first CS primitives (see Table 1) are used mainly for periodic LU. They can be used also in the case where the MN initiates a LU procedure by sending the third CS message shown in Table 1.

Table 1. Proposed MIH CS and IS primitives for proxying LU

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIH_Location_Update</td>
<td>MIH CS</td>
<td>To perform a LU (WiMAX &amp; LTE)</td>
</tr>
<tr>
<td>MIH Link Location_Update</td>
<td>Link CS</td>
<td>LU-Req (WiMAX) &amp; TAU (LTE)</td>
</tr>
<tr>
<td>Net MIH Location_Update</td>
<td>MIH CS</td>
<td>MN initiate a LU procedure</td>
</tr>
<tr>
<td>MIH Get Information</td>
<td>MIH IS</td>
<td>List of T/P areas for the MN location</td>
</tr>
</tbody>
</table>

The last IS information primitive, in Table 1, is already defined in [7] \textit{(MIH\_Get\_Information\_request/response)} is used by MNs to request information and to receive response from the IS server. In order to support our proposed approach, we need to extend the parameter ‘‘\textit{INFO\_ELEMENT}’’ (in the response) with a new IE (Information Element) called ‘‘IE\_Paging\_Tracking\_Area\_ID’’. This IE will be used to carry the identification of a paging/tracking area. Upon receipt of MN request \textit{(MIH\_Get\_Information\_request)}, the IS server specifies in the response the list of all paging/tracking areas that cover the current MN location. Obviously, both the MN and the IS server should be capable of generating and interpreting the request and the response primitives correctly.

\subsection*{4.4 Extension of IS database}

For the IS to respond properly to the extended MIH\_Get\_Information\_request, we propose the extension of its database with geographic information of its managed paging/tracking areas.

To populate the database with the geographic coverage of each paging/tracking area, the IS server could use the existing information related to the PoAs. The concerned information consists on, the geographic position of PoAs and their radio coverage area (radius). The information that has to be added in the IS server (database) are the paging/tracking areas identification of the managed networks. A table could be used to identify which paging/tracking areas each PoA belongs to. Thus, given the geographic position of the MN, the IS server could determine the list of paging/tracking areas serving the MN.

So, when the IS receives the request message \textit{(MIH\_Get\_Information\_request)} indicating the geographic position of the MN, it just identifies the paging/tracking areas that are covering this position and then sends them in a list to the requesting MN.

\section*{5. ANALYSIS}

\subsection*{5.1 Energy consumption}

To evaluate the energy saving during one day of usage ($T_0 = 24$ hours), we consider 3 types of users [10]: low, moderate and heavy usage user. The total active time for each user (1, 2 and 3) is respectively $T_1 = 30$, $T_2 = 140$ and $T_3 = 300$ minutes.

In this section, we compute the total energy consumed by the radio interfaces of a multi-radio interface MN in 3 scenarios: (1) When the radio interfaces, namely WiMAX and 3G, of the MN are not proxied; in this case, power management of each radio interface is performed individually as in existing solutions; (2) The MN interfaces are proxied but location updates, triggered by MN mobility, are not considered; and (3) The MN interfaces are proxied and location updates, triggered by MN mobility, are considered. Wi-Fi interface is not proxied in all 3 cases since the idle mode and location update for Wi-Fi are not defined in 802.11.

For each scenario, we consider that the MN is equipped with two radio interfaces: Wi-Fi and WiMAX/3G. In the three scenarios and during all the usage period $T_0$, the active time of the two radio interfaces is equally shared between them, this is also true, for the time of transmit and receive of the data. Half of the active period, of an interface, is used to transmit data and the other half is used to receive data it.

The parameters considered in this evaluation are: (1) $t_{LU}$ which corresponds to the time interval between two consecutive location updates; (2) $t_{LC}$ which corresponds to the frequency of location (paging/tracking area) change that triggers a LU procedure; (3) $T_{D}$ is the duration of a location update procedure and (4) $T_{TR}$ is the transition switching (on/off) time. The values of these parameters are shown in Table 2.

Table 2. Values of the parameters used in the evaluation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{LU}$</td>
<td>$25 \leq t_{LU} \leq 4095$ seconds</td>
</tr>
<tr>
<td>$t_{LC}$</td>
<td>$200 \leq t_{LC} \leq 14400$ seconds</td>
</tr>
<tr>
<td>$T_{D}$</td>
<td>$\sim 50$ milliseconds</td>
</tr>
<tr>
<td>$T_{TR}$</td>
<td>$\sim 100$ milliseconds</td>
</tr>
</tbody>
</table>

According to [9, 10, 11], the power consumptions for each radio interface in transmit mode ($P_{TX}$), receive mode ($P_{RX}$) and idle mode ($P_{idle}$) are shown in Table 3.

The total time of using the IS service is $T_{IS} = \frac{1}{2} * T_{LC}$ (with $T_{LC} = T_{LU} / t_{LC} * T_{D}$). The total time of using the location system is $T_{GPS} = T_{LU}$ (with $T_{LU} = T_{LU} / t_{LU} * T_{D}$). The power consumed by GPS chip is $P_{GPS} = 45 \text{mW}$ [12].

Table 3. Power consumptions values of wireless interfaces in different modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Wi-Fi</th>
<th>WiMAX</th>
<th>3G</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{TX}$</td>
<td>890 mW</td>
<td>530 mW</td>
<td>1100 mW</td>
</tr>
<tr>
<td>$P_{RX}$</td>
<td>690 mW</td>
<td>510 mW</td>
<td>555 mW</td>
</tr>
<tr>
<td>$P_{idle}$</td>
<td>256 mW</td>
<td>80 mW</td>
<td>19 mW</td>
</tr>
</tbody>
</table>

\[1\] Figure 5. Proxy Design on Anchor PC

\[2\] Table 3. Power consumptions values of wireless interfaces in different modes

\[3\] Table 2. Values of the parameters used in the evaluation

\[4\] Table 1. Proposed MIH CS and IS primitives for proxying LU

\[5\] Table 1. Proposed MIH CS and IS primitives for proxying LU

\[6\] Table 1. Proposed MIH CS and IS primitives for proxying LU

\[7\] Table 1. Proposed MIH CS and IS primitives for proxying LU

\[8\] Table 1. Proposed MIH CS and IS primitives for proxying LU

\[9\] Table 1. Proposed MIH CS and IS primitives for proxying LU

\[10\] Table 1. Proposed MIH CS and IS primitives for proxying LU

\[11\] Table 1. Proposed MIH CS and IS primitives for proxying LU
The evaluation of energy saving achieved with each of the two proposed approaches, consists of comparing the energy consumed with the single radio power management (existing one) and our two approaches. The comparison consists simply on computing the consumed energy using three approaches. Recall that the second and the third approaches are respectively proxying interface without considering MN mobility and proxying interface considering MN mobility. To evaluate the performance of our proposed approaches (approaches 2 and 3) we consider three user profiles (Low, Moderate and High) as presented above. The evaluation is made individually for both radio interfaces (WiMAX and 3G).

To quantify the energy savings using our two approaches; we compare the difference of the consumed energy using (1) approach 1 (single radio approach) versus approach 2 (proxying radio interface without considering MN mobility); and (2) approach 1 versus approach 3 (proxying radio interface considering MN mobility) respectively. This computation is performed for the three user profiles and the two radio interfaces (WiMAX and 3G). Notice that the x-axis (of Fig. 6) corresponds to the time interval (tLC) between two consecutive (periodic) location updates required by the network system (200 ≤ tLC ≤ 14400 seconds; see Table 2).

Fig. 6 shows the energy savings when the interfaces are proxied without considering MN mobility; the maximum of energy saving is achieved when (1) proxying WiMAX interface; it is around 7000J, which is more than 80% of the total energy consumed when this interface is not proxied, as shown in Fig. 6(a); and (2) proxying 3G interface; it is around 1500J, which is more than 45% of the total energy consumed when this interface is not proxied, as shown in Fig. 6(b). This difference in energy saving (between the two interfaces) is due to the fact that the power consumption in idle mode for WiMAX interface is much more important than for 3G interface. For both interfaces the energy saving decreases (relatively) when we move from a low usage to a higher usage.

The same trend (not shown because of lack of space) shown in Fig. 6 is observed for approach 3 with less energy saving (10 to 20% less than approach 2); the difference is due to the fact that MN (using approach 3) uses a GPS system to detect its position, checks with the IS whether it has changed the location (paging/tracking area) and reports to the PC/MMN its new location. The gains in energy savings, using approach 2, come at a price: longer delays (not shown because of lack of space), compared to approach 3, to wake-up the proxied interface.

In both approaches, the time interval of location update doesn’t seem to influence the energy saving when it is more than 250s. This means that the consumed energy (in 1 day) due to the periodic location update is significant when tLC is between 25-250s (very frequent), and less important (less frequent) beyond 250s. The ratio of energy saving for both interfaces (and for both approaches) is much important for lower usage users.

6. Conclusion
In this paper, we proposed new proxying mechanisms, for the location updates, and the extension needed on IMIP framework and 802.21 services (primitives) for its realization. Proxying location update procedure, definitely reduces (or may eliminate) the necessity to power-on the proxied interfaces to perform a location update; this allows for considerable MN energy saving. The evaluation of the power savings, using the proposed LU proxying mechanisms based on daily usage of a multi-radio MN for three types of users, has shown that the proposed proxying mechanisms improved considerably the power savings, compared with existing schemes (single-radio power management).

7. REFERENCES

Figure 6. Energy saving when proxying (a) WiMAX, (b) 3G idle interface without considering MN mobility.