Energy Optimization Mechanism for Mobile Terminals using Vertical Handoff between WLAN and CDMA2000 Networks

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Abstract

This paper presents energy optimization mechanism for mobile terminals (MTs) using vertical handoff between Wireless LAN (WLAN) and CDMA2000 networks. Several techniques for optimizing the power consumption of MTs have been considered in literature. Some of these techniques could be used separately or in tandem. Considering the importance of efficient energy management for MTs, the research in this area could be taken a step further. The technique considered in this paper allows a multimode terminal to take advantage of two integrated networks to efficiently manage its energy consumption. Two integrated networks considered are WLAN and CDMA2000. This paper develops an algorithm that allows the MT to always get connected to the most cost-effective network. The results obtained showed that the MTs power is more efficiently managed when the MT is using the integrated networks than when it is using each of the networks independently.

Keywords

WLAN, CDMA2000, NIC, VHO, MT, energy optimisation, multimode device, service time, user’s preference indicator.

Introduction

In recent times, the use of Internet has allowed users ease of communication access at anywhere at any time. There are also emerging voice and data networks, each requiring mobile access devices. The need for users to take advantage of the various access networks without carrying about multiple terminals has lead to the development of multimode terminals. Most popular types of these multimode terminals presently are those that can access wireless LAN (WLAN) and CDMA2000 networks. Also, the users' desire to be always best connected anytime, anywhere, with any device has fuelled the research on network integration. Network integration has been shown to have good prospects to both users and network providers alike.

The release of the IEEE 802.11 WLAN standards in 1997 gave rise to a number of other related standards which form the 802.11 family of standards. These standards were made to facilitate the interoperability of WLANs, and allow for the introduction of several new services. One of these services introduced is the public wireless access data networks more commonly known as "hot-spots". The great success and massive recent deployment of WLAN technology indicates that these networks will play an important role in the development of the 4G networks [1]. To achieve the dream of universal mobile telecommunications as specified by the international telecommunications union (ITU), it is necessary to integrate WLAN and CDMA2000 cellular networks. The Internet certainly, will be used to support this integration because it has become the main thrust of network integration between complementary heterogeneous networks.

WLAN hot-spots and CDMA2000 cellular network are complementary wireless access technologies. Their integration could help to meet the end user's demand for improved access to services using a "single multi-mode" devices that are mobile and portable with longer battery life. Recent trends indicate that WLAN based on IEEE 802.11 standards and third generation (3G) wireless wide area network such as CDMA2000 Cellular network will co-exist to offer easy Internet access to end users [2, 3].

Modern technologies have reduced the burden of carrying bulky computing equipment around or on transit by users. Multimode mobile devices [4] are also fast becoming affordable and a growing number of portable computer systems such as laptops, personal digital assistants (PDAs), hand-held etc. are now equipped to connect to different networks.

One issue which is fundamental to mobile wireless devices is power conservation. It has been shown that different network interfaces attached to the MTs consume power at different rates [5]. The power consumption rate is dependent on the network to which the MT is connected, and also on the state of the MT, which may be transmitting, receiving or idle state. Based on this, the power consumption of a multimode MT could be optimized via the use of integrated networks. This could be done by configuring the MT to automatically select the most cost effective network, not only in terms of bandwidth consumption, as has always been considered in literature, but also in terms of power consumption and user's preference. This paper considers an algorithm that enables MTs with WLAN and CDMA2000 interfaces to automatically select the most cost-effective network which optimizes the MT's power consumption without degrading the network performance.

The rest of this paper is arranged thus: Section 2 gives the description of the power optimization method, Section 3 presents the power optimisation algorithm with its flow chart, Section 4 presents the performance evaluation and Section 5 presents the conclusion and future works.

Description of the Optimization Method

In this section, we present the proposed energy optimization model that makes use of vertical handoff to support the optimization of MT's power consumption without network degradation. This is an algorithm that makes the MT to select the best network (CDMA2000 or WLAN) in terms of power consumption rate of their network interface card (NIC) respectively at a time without reduction in QoS. Before the MT enters a given state, the decision model computes the energy consumption for each NIC with respect to that state. The decision on what interface to be selected is based on the outcome of the computation. The interface with lower power consumption rate is activated while the other is deactivated. NICs generally can be in any one three conditions (Uploading or transmitting, downloading or receiving and idle or redundant mode) when activated. Table 1 shows the power consumption requirements of two NICs (CDMA1x wireless modem and Orinoco IEEE802.11b wireless LAN modem) as reported in [6, 7] used as a case study in this paper.

Table 1. CDMA1x wireless modem and Orinoco IEEE802.11b wireless LAN modem as reported in [6, 7].

MT's state: Power consumption of	Uploading or transmitting	Downloading or receiving	Idle or redundant
CDMA1x wireless modem	2.800 (W)	0.495 (W)	0.082 (W)
Orinoco IEEE802.11b wireless LAN modem	1.300 (W)	0.900 (W)	0.740 (W)

Basically, the algorithm uses three parameters to make a decision. These are: NIC power consumption rate at each state of each network denoted as *p* in watts, time required to deliver the required service (service time), denoted as *t* in seconds and User's preference indicator (1 or 100) denoted as *u*. This preference indicator allows a user to be on a particular network of his choice for whatever reason, irrespective of power consumption. This is done to lend flexibility to the algorithm. If $u = 1$ is selected for any of the networks while maintaining the other network at $u = 100$, the MT will be permanently connected to the network whose *u* is 1 because the power consumption weight of this preference is lower. On the other hand, if *u* is equal for both networks, i.e. $u = 1$ or $u = 100$, the decision to which network the MT is connected would be based on the outcome of the computation in equation (1). With these parameters, an energy consumption function computes the energy requirement *E*, in Joules, by each NIC in the given state.

$$E = p \times t \times u \tag{1}$$

For the NICs considered in this work, the possible energy consumption options for the two networks are given in equations (2) and (3) respectively.

$$E_W = \begin{cases} 1.3 \times t \times u & \text{MT on upload state} \\ 0.9 \times t \times u & \text{MT on download state} \\ 0.74 \times t \times u & \text{MT on idle state} \end{cases} \tag{2}$$

$$E_C = \begin{cases} 2.8 \times t \times u & \text{MT on upload state} \\ 0.495 \times t \times u & \text{MT on download state} \\ 0.082 \times t \times u & \text{MT on idle state} \end{cases} \tag{3}$$

where E_W is the WLAN NIC energy consumption rate required for the state in demand and E_C is the CDMA2000 NIC energy consumption rate required for the state in demand.

Description of the optimization algorithm with flow chart

In this section we present the algorithm that implements the power optimization for a multimode MT. When an MT is powered on, it connects to one of the two available networks.

Before it enters any given state, E_W and E_C are first computed using the algorithm. The result of this computation will make the algorithm decide to which network the MT should switch to via vertical handoff. This is done by comparing the two computed energy consumption values. The NIC with the least energy consumption value is selected. If it is the NIC for the current network, no vertical handoff is initiated. Otherwise, a vertical handoff is initiated so as to handoff the MT's transactions to the network with better energy consumption. Note that the user is unaware of these switches; he only observes that his MT's power lasts longer. The flow chart is laid out in Figure 1. Note also that the algorithm indirectly contributes to load balancing in the network system, since service time is estimated and factored into the decision engine. So likelihood of network congestion is reduced.

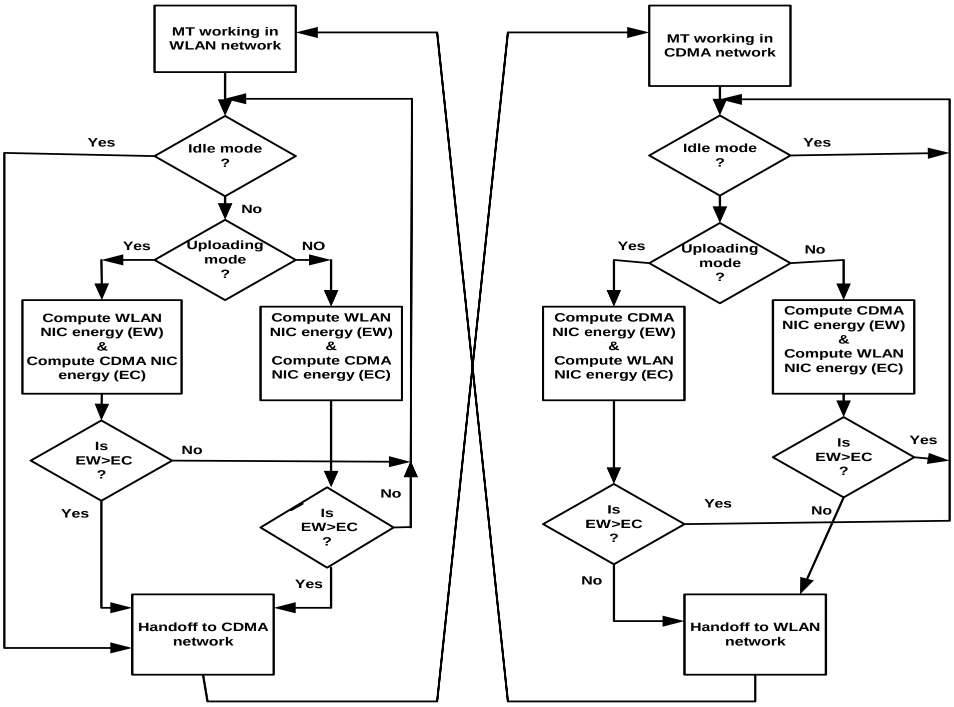

Figure 1. Flow chart for the power optimization algorithm

Performance Evaluation

This section presents the effect of the power optimization algorithm on MT power consumption. Several data downloads from the Internet were made using the three different states (Idle, Download and Upload) a MT could be in a time. In each case, we estimated the time required to perform the requested service was estimated. This is denoted as service time (t) in seconds. Let Idle state, Download state and Upload state be denoted by ID, DL and UP respectively. In addition, User Preference (u), which may allow the user to remain in the preferred network regardless of the network's performance is turned off by setting u = 1 for both networks in this evaluation. This is done to demonstrate the energy saving effect of the algorithm. Parameter values used for evaluation are shown in Tables 1 and 2.

Table 2. Parameters for performance evaluation

NIC state	ID	DL	UP	ID	UP	DL	ID	DL	UP	ID	UP	DL
t (s)	30	120	60	20	100	130	60	40	125	40	30	60
U	1	1	1	1	1	1	1	1	1	1	1	1

Power consumption rates for WLAN network, CDMA2000 network, and the proposed VHO mechanism are presented in Figures 2, 3 and 4 respectively. In each case, we plotted energy consumption against service time was plotted to show power management trend of the MT in each network.

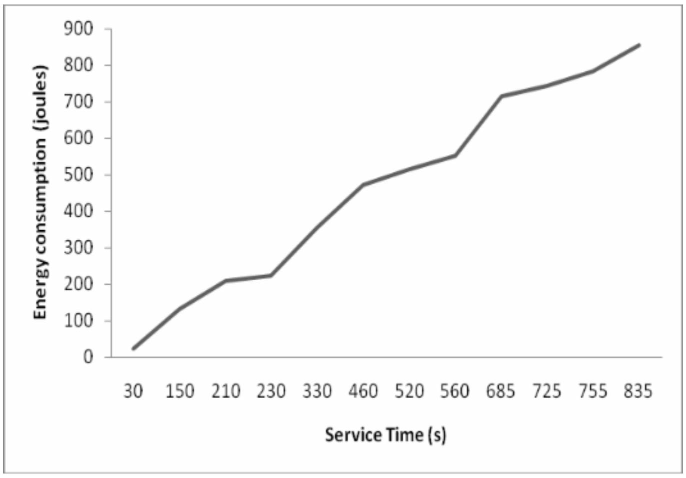

Figure 2. Power consumption rate of MT when on WLAN alone

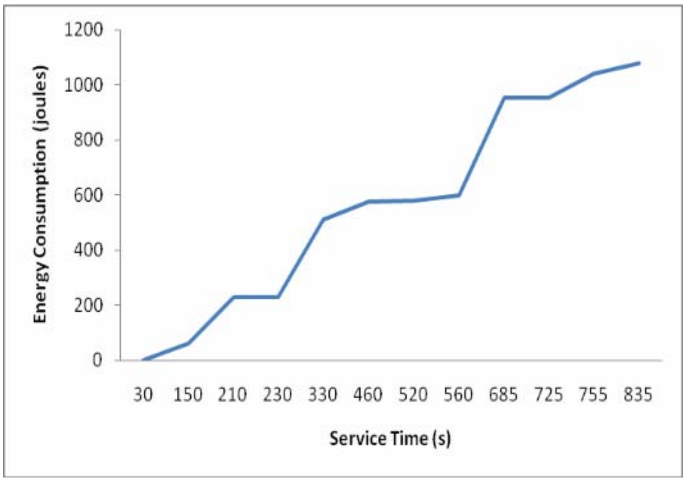

Figure 3. Power consumption rate of MT when on CDMA2000 alone.

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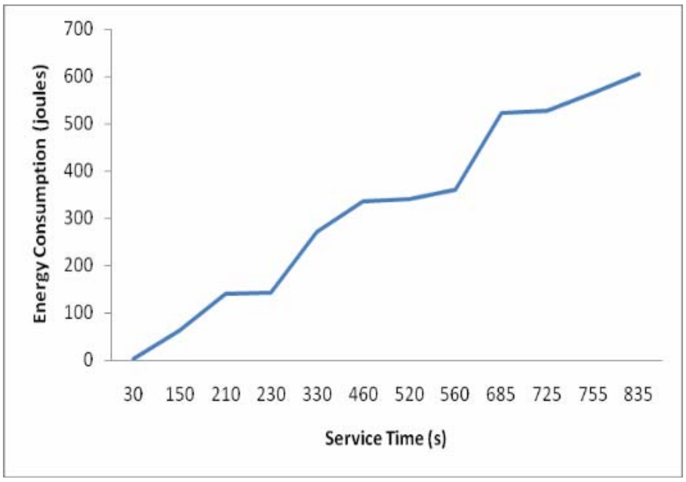

Figure 4. Power consumption rate of MT while on integrated network running our algorithm.

From Figure 2, it could be observed that over 800 joules of energy was consumed by the MT for a period of 835 seconds while in Figure 3, it could also be seen that over 1000 joules of energy was consumed by the MT for the same period of 835 seconds. But in Figure 4, it could be seen clearly that a little above 600 joules of energy was consumed for the same 835 seconds. This shows a significant improvement over the first two cases. This means that a MT's power can be better conserved when used in an integrated network involving WLAN and CDMA2000 network.

The plot of the three scenarios on the same axis for effective comparisons is hereby presented in Figure 5.

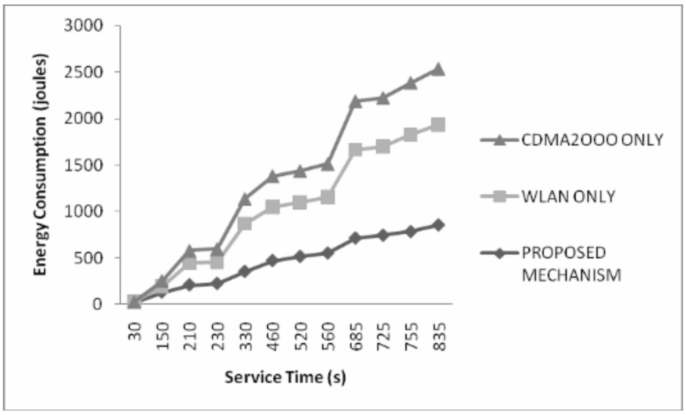

Figure 5. Compares of energy consumption for the three scenarios

Conclusion and Future Works

This paper proposed an energy optimisation mechanism for MT using VHO between WLAN and CDMA2000 network. We designed an algorithm that could provide efficient power management in MTs without network degradation. The power consumption rates of the two popular NICs, one for each network, were used to carry out this work. The result shows that our proposed mechanism performs considerably well. The benefits of the two complementary heterogeneous networks have also been discussed. There are, however other issues that are not addressed in this paper such as network QoS, network security, handoff latency etc. These could be considered as future works in this area.

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