Low-power Hibernation Technique for WUSB over IEEE 802.15.6 Hierarchical MAC

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Abstract. In this paper, we integrate the IEEE 802.15.6 wireless body area networks (WBAN) with the wireless USB (WUSB) system to develop wireless communication technologies for wireless wearable computer systems. Due to portable and wearable nature of the wearable computer systems, the WUSB over IEEE 802.15.6 hierarchical medium access control (MAC) protocol has to support the power saving operation and integrate WUSB transactions with WBAN traffic efficiently. In this paper, we propose a low-power hibernation technique (LHT) for WUSB over IEEE 802.15.6 hierarchical MAC to improve its energy efficiency.

Keywords: Hierarchical MAC, Wearable Computer, Wireless USB, Wireless Body Area Networks (WBAN).

1 Introduction

A recent major development in computer technology is the advent of the wearable computer system that is based on human-centric interface technology trends and ubiquitous computing environments []. Wearable computer systems use the wireless universal serial bus (WUSB) that refers to USB technology that is merged with WiMedia PHY /MAC technical specifications, [2-6]. A wireless body area network (WBAN), which describes the application of wearable computing devices, allows the integration of intelligent, miniaturized, low-power, invasive/non-invasive sensor nodes that monitor body functions and the surrounding environment [7].

The WUSB channel is a continuous sequence of linked application-specific control packets, called micro-scheduled management commands (MMCs). WUSB maps the USB 2.0 transaction protocol onto the TDMA micro-scheduling feature. Within the WUSB protocol, the micro-scheduled sequence consists of an MMC and the subsequent time slots that are described in the MMC; this sequence is called a transaction group [4]. The WUSB host dynamically manages the size of transaction groups over time according to the demands of the endpoint data streams. Therefore, the number of transactions per transaction group can be variable. MMCs are used by a host to control WUSB channel. A WUSB network consists of a WUSB host and several WUSB devices, and this is referred to as a WUSB cluster [4]. In a similar manner, IEEE 802.15.6 WBAN hubs and sensor nodes form a star topology [7]. In the

WUSB over WBAN Architecture, in order to set up a wireless communication link to wearable computer systems, secure WUSB channels should be encapsulated within a WBAN superframe. This enables the MMC scheduling between WUSB host and its several peripheral devices without contention.

2 Low-Power Hibernation Technique for WUSB over WBAN Architecture

WBAN slave devices which have received beacon from WBAN host schedule their receiving and transmitting operations according to information delivered by the beacon. IEEE 802.15.6 WBAN superframe begins with a beacon period (BP) in which the WBAN hub performing the WUSB host's role sends the beacon. This beacon mode of the WBAN is operated in both non-medical and medical traffic environments. The data transmission period in each superframe is divided into the exclusive eccess phase 1 (EAP1), random access phase 1 (RAP1), Type-I/II access phase, EAP2, RAP2, Type-I/II access phase, and contention access phase (CAP) periods. The EAP1 and EAP-2 periods are assigned through contention to data traffic with higher priorities. Further, the RAP1, RAP2, and CAP periods are assigned through contention to data traffic with lower priorities.

The IEEE 802.15.6 WBAN MAC systems have several MAC Capability options. We denote the WUSB slave device which also performs the WBAN slave device function as WUSB/WBAN slave device. The WUSB/WBAN slave devices keep its active mode during an entire superframe if the Always Active field is set to one in the received beacon in that superframe. Otherwise, if the Always Active field is set to zero, the WUSB/WBAN slave devices keep its active mode during only the beacon period and other allocated periods for that superframe. This operation is called as the hibernation.

The duty cycle and length of the hibernation in the IEEE 802.15.6 WBAN systems can be varied according to the WBAN system requirements. If a WUSB/WBAN slave device wants to sleep during several superframes, it set the Wakeup Period field in the Connection Request control frame and sends the Connection Request control frame to the WUSB/WBAN host. If the value of Wakeup Period field is equal to m, it means that the slave device sleeps during m-1 superframes and turns into active mode at the mth superframe. The Wakeup Phase field in the Connection Request control frame indicates the sequence number of superframe where the device turns into active mode. After receiving the Connection Request control frames from WUSB/WBAN slave devices, the WUSB/WBAN host has to store information of Wakeup Period and Wakeup Phase fields.

If the Wakeup Period field in the Connection Assignment control frame which the WUSB/WBAN host sends is set to a non-zero value, it means that the host assigns the m-periodic allocation to its slave devices. At the m-periodic allocation, WUSB/WBAN slave devices receive and transmit frames after m-1 superframes. Through the hibernation technique, the WUSB over WBAN hierarchical network turns into active mode during only predetermined superframes. At the case of m-periodic allocation, the WUSB/WBAN hierarchical network only stay in the active status during T/m time

for entire T time. Therefore, the hierarchical network saves power consumption during (T-T/m) time for entire T time. The WUSB/WBAN host should transmit WUSB data without interference with WBAN data when a request for WUSB data transmissions occurs in the WUSB cluster. For this purpose, the WBAN host which also performs the function of WUSB host allocates the WUSB private channels at the RAP2 period. At the m-periodic allocation hibernation, there are m-1 inactive superframes.

In this paper, an efficient WUSB private channel allocation method of LHT is proposed. In this method, the WUSB private channels are allocated during the inactive periods to improve channel utilization. When a request for WUSB data transmissions occurs at the WUSB host or WUSB slave-devices in the WUSB cluster, WBAN host which also performs the function of WUSB host sets the Private Period Allocation field to one in the MAC capability field. And the WUSB/WBAN host also sets the WBAN beacon's RAP2 length field to the length of inactive periods required for MMC scheduling in the WUSB private channel. Then, the WUSB/WBAN host transmits its beacon frame. And the Wakeup Period field in the Connection Assignment control frame which the WUSB/WBAN host sends is set to a non-zero m value. And the Wakeup Phase field in the Connection Assignment Frame set to a sequence number of superframe increased by m. After receiving beacon and Connection Assignment control frames, non-WUSB WBAN slave devices enter into sleep mode during m superframes. On the contrary, the WUSB/WBAN host and slave devices enter into active mode at every RAP2 period during consecutive m superframes, for the WUSB transactions.

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