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Wearable Computer Network Design using Dual-Role WUSB Clustering

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Abstract

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 can be integrated with the wireless universal serial bus (WUSB) that refers to USB technology that is merged with WiMedia PHY/MAC technical specifications. A wireless body area network (WBAN) allows the integration of intelligent, miniaturized, low-power sensor nodes that monitor body functions and the surrounding environment. In this paper, we propose a method for multi-hop network extension of WUSB over WBAN protocol. Unlike a wired USB that physically separates the USB host and USB device, WUSB allows a device to separately function as both a WUSB host and WUSB device on a single transceiver; such devices are referred to as the dual role devices (DRD). By using this DRD function of WUSB protocol, we propose a WUSB clustering method to realize the multi-hop network extension of WUSB over WBAN protocol in wireless home networks. In the WUSB clustering method, a new DRD message format reserves 2-hop range private DRP (Distributed Reservation Protocol) resources. In the experiment results, efficiency of the WUSB clustering method is proven through throughput evaluation in viewpoints of medical and nonmedical multi-hop WBAN services.

Keywords: *Body Sensor Networks, Home networks, IEEE 802.15.6, Multi-hop, Wireless USB, Wearable Computer*

1. Introduction

Development in wireless communication and the miniaturization of computing devices, such as wearable and implantable sensors, enable next-generation communication known as body sensor networks (BSNs). Each BSN comprises several intelligent sensor nodes that should have a communication range of 3 m and dynamic data rates from 10 kbps to 10 Mbps according to application requirements [1]. Each sensor nodes monitors a human's biometric or surrounding environment information, and forward it to a hub.

A wearable medical system may encompass a wide variety of components: sensors, wearable materials, smart textiles, actuators, power supplies, wireless communication modules and links, control and processing units, interface for the user, software, and advanced algorithms for data extracting and decision making. Wearable computer systems use the wireless universal serial bus (WUSB) that refers to USB technology that is merged with WiMedia PHY/MAC technical specifications. WUSB can be applied to wireless personal area networks (WPAN) applications as well as wired USB applications such as PAN. Because WUSB specifications have defined high-speed connections between a WUSB

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host and WUSB devices for compatibility with USB 2.0 specifications, the wired USB applications are serviced directly [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. Each intelligent node has sufficient capability to process and forward information to a base station for diagnosis and prescription [7].

In this paper, we propose a method for multi-hop network extension of WUSB over WBAN protocol. Unlike a wired USB that physically separates the USB host and USB device, WUSB allows a device to separately function as both a WUSB host and WUSB device on a single transceiver; such devices are referred to as the dual role devices (DRD). By using this DRD function of WUSB protocol, we propose a WUSB clustering method to realize the multi-hop network extension of WUSB over WBAN protocol in wireless home networks. In the WUSB clustering method, a new DRD message format to reserve 2-hop range private DRP (Distributed Reservation Protocol) resources. In the experiment results, efficiency of the WUSB clustering method is proven through throughput evaluation in viewpoints of medical and nonmedical multi-hop WBAN services.

2. Related Works

A WBAN hub shall place the access phases—exclusive access phase 1 (EAP1), random access phase 1 (RAP1), managed access phase (MAP), exclusive access phase 2 (EAP2), random access phase 2 (RAP2), another managed access phase (MAP), and contention access phase (CAP)—in the order stated and shown above. The hub may set to zero the length of any of these access phases, but shall not have RAP1 end before the guaranteed earliest time as communicated in Connection Assignment frames sent to nodes that are still connected with it. To provide a non-zero length CAP, the hub shall transmit a preceding B2 frame. The hub shall not transmit a B2 frame if the CAP that follows has a zero length, unless it needs to announce B2-aided time-sharing information and/or provide group acknowledgment [7].

Only in a MAP, the hub may arrange scheduled uplink allocation intervals, scheduled downlink allocation intervals, and scheduled blink allocation intervals; provide unscheduled blink allocation intervals; and improvise type-I, but not type-II, immediate polled allocation intervals and posted allocation intervals starting in this MAP. In an EAP, RAP, or CAP, or MAP, as shown in Fig. 1, the hub may also improvise future polls or posts starting and ending in a MAP.

Figure 1 shows the WUSB over WBAN architecture. In the proposed WUSB over WBAN Architecture, in order to set up a wireless communication link to wearable computer systems, the WUSB channel is encapsulated within a WBAN superframe via Type-I/II access phase periods that enables the WUSB host and the input-sensor nodes to reserve time slots without contention through MMC scheduling. In the user scenario of a wearable computer system when using the WUSB over WBAN architecture, the user carries a portable or wearable computing host device.

This host device performs roles of the WUSB host and the WBAN hub simultaneously. Therefore, a “wearable” WUSB cluster and a WBAN cluster are formed. The attached input-sensor nodes perform the functions of localization-based input interfaces for wearable computer systems and healthcare monitoring. Furthermore, the attached wireless nodes comprise the peripherals of a wearable computer system, and the central WUSB host exchanges data with the outer peripherals of the WUSB slave devices.

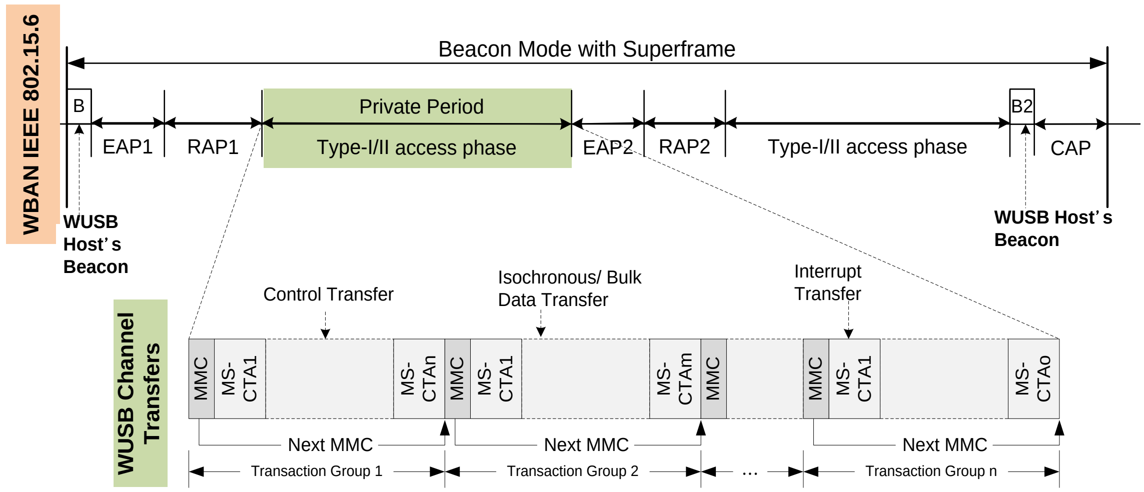

Figure 1. WUSB over WBAN Architecture

3. Multiple Wearable Computer Network Configuration

WUSB allows a DRD to operate separately in time as a WUSB host and as a WUSB device on a single transceiver. A number of scenarios are possible for DRD devices including 'combination' and 'point-to-point' scenarios [4]. In the combination scenario, the DRD operates as a WUSB device connected to a WUSB host. Separately in time, the same DRD also operates as a WUSB host that manages other WUSB devices. On the other hand, in the point-to-point scenario, two DRDs connect themselves with each other as both a WUSB host and a WUSB device. In the WUSB specification [4], the WUSB host operating mode in a DRD is denoted as DRD-host, and the WUSB device operating mode in a DRD is denoted as DRD-device.

In Figure 2, a WUSB cluster tree topology is formed to configure multiple wearable computer networks (WCN). Basically, a single WCN operates based on WUSB over WBAN protocol. And the host in each network denoted as H1 takes a role of DRD-host or DRD-device. The WUSB/WBAN flows in a network are manipulated in a time period during a WBAN superframe. On the other hand, the DRD flows between WCNs are manipulated in a time period during a WiMedia D-MAC superframe, as shown in Figure 3. By adopting the D-MAC, our WCN solves the SOP problem in the centralized IEEE 802.15.3 MAC. In the D-MAC, each node broadcasts its own beacon containing IEs per a superframe. The IEs convey certain control and management information. The distributed nature of D-MAC protocol can provide a full mobility support and a scalable and fault tolerant medium access method to a multiple WCN environment.

In this WUSB cluster tree, the DRD-device H2 in WUSB cluster 2 and the DRD-device H3 in WUSB cluster 3 are connected with the DRD-host H1 in WUSB cluster 1. And the DRD-host H1 in the WUSB cluster 1 can manage WUSB devices belonging to WUSB cluster 2 and WUSB cluster 3 as well as WUSB member devices in its own WUSB cluster. In this way, large scale multi-hop WCNs can be constructed.

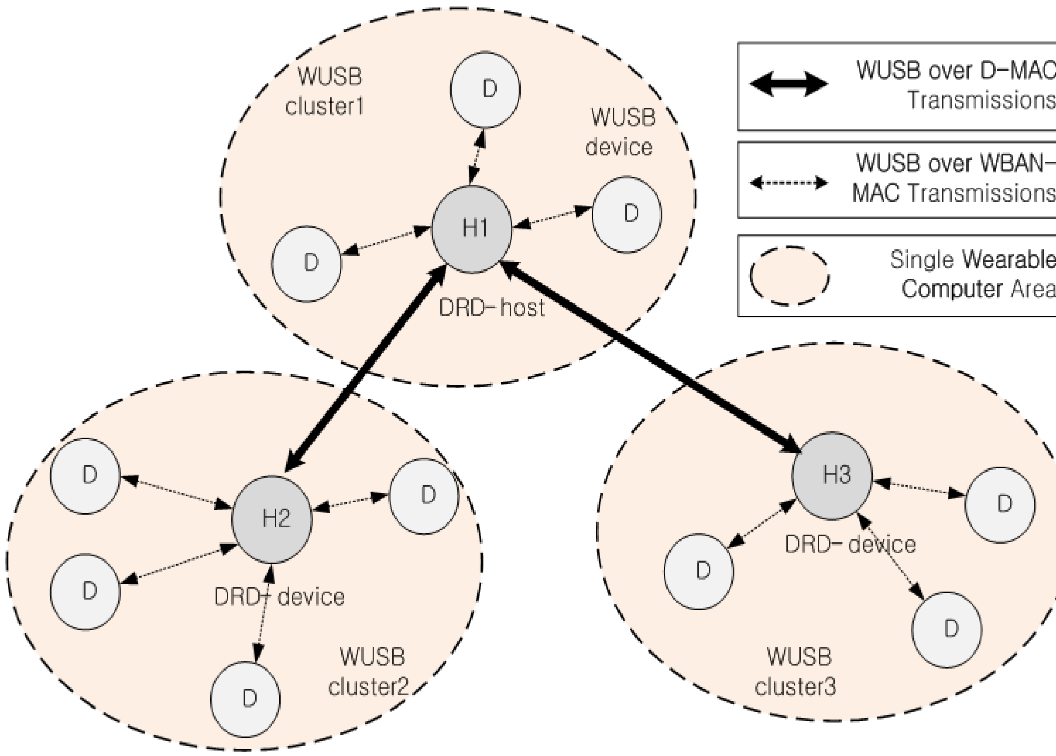

Figure 2. A WUSB Cluster Tree Topology for Multiple Wearable Computer Networks

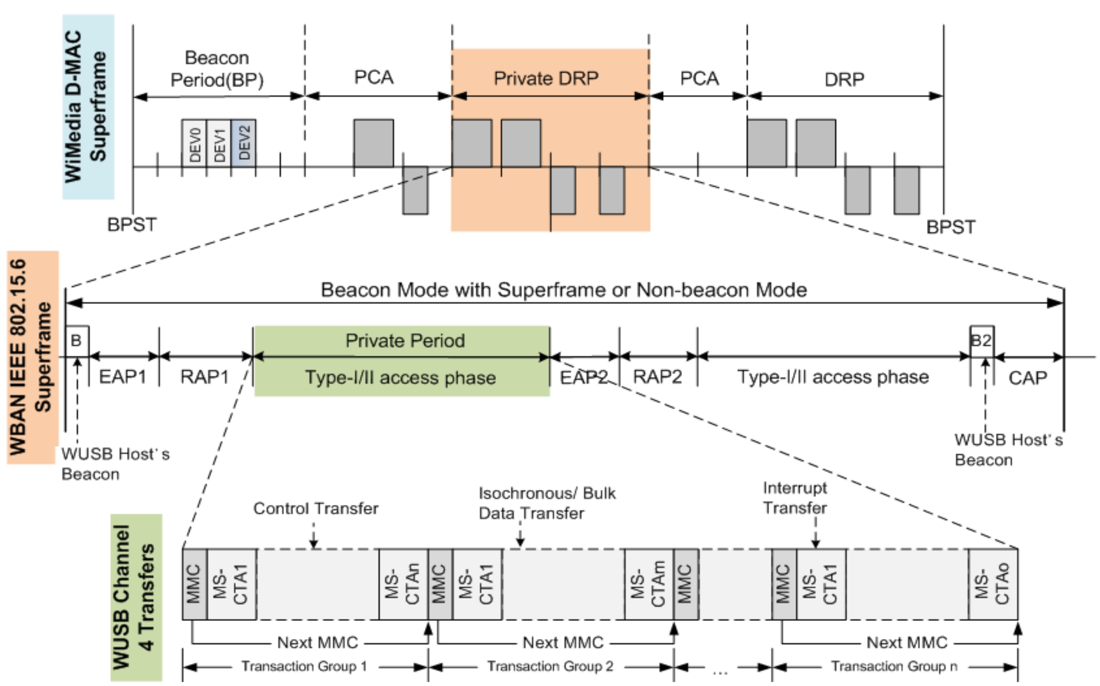

Figure 3. WUSB Flows and DRD Flows Allocation for Multiple Wearable Computer Networks

4. Experiments

We designed the multiple WCN and simulated it for performance evaluation with WBAN medical/non-medical service parameters and WiMedia PHY/MAC parameters as in Tables 1, 2 and 3 [8-11]. In the simulation, the single WCN network size is 2.5m*2.5m and three WCNs are connected through the DRD function. One WUSB/WBAN host and four WUSB/WBAN bio-sensor devices with CCA function turned on are deployed into each WCN. WBAN frame size is fixed to 4095 bytes.

Table 1. WBAN Medical Service Traffic Parameters

Service	Service data rate	Setup Time
EEG	*86.4kbps*	*< 3s*
ECG	*3kbps/ch*	*< 30s*
Vital monitor	*< 10kbps*	*< 30s*
SpO2	*< 32kbps*	*< 30s*
Hearing aid(communication)	*10kbps*	*< 1s*
Hearing aid(medium fidelity)	*256kbps*	*< 3s*
Glucose/brain liquid/drug delivery capsule	*< 1kbps*	*< 3s*
Endoscope capsule	*1Mbps*	*< 3s*
Brain-computer interface	*2Mbps*	*< 1s*
Pacemaker/ICD/actuator/insulin pump	*10kbps*	*< 3s*

Table 2. WBAN Non-medical Service Traffic Parameters

Service	Service data rate	Setup Time
Video streaming	*10~20Mbps*	*< 1s*
3D video	*100Mbps*	*< 1s*
Voice comm.	*256kbps*	*< 3s*
Sound track	*5Mbps*	*< 3s*
File transfer	*10Mbps*	*< 3s*
Gaming applications	*200kbps~2Mbps*	*< 1s*

Table 3. WiMedia PHY/MAC Parameters

Parameter	Value
T_{SYM}	312.5ns
T_{sync}	Standard Preamble: 9.375μs
pMIFS	1.875μs
pSIFS	10μs
mMAXFramePayloadSize	4,095 octets
mMAXBPLength	96 beacon slots
mBeaconSlotLength	85μs
mSuperframeLength	256*mMASLength
mMASLength	256μs
mBPExtension	8 beacon slots
mTotalMASLimit	112 MASs

Figure 4 depicts throughput of received WBAN data frames at multiple WCNs environment. Without DRD and WiMedia D-MAC connectivity in the legacy scheme, the sum of received data frames do not increase largely because the WUSB/WBAN device is interfered by WUSB flows of the other WCN. However, throughput of received data frames increases largely when using our WCN configuration scheme. If the DRD-host H1 finds clean D-MAC channel for the DRD-devices H2 and H3 in Figure 2, each WUSB/WBAN host sets up clean WBAN channel for its WUSB/WBAN flows without interference from other WCN's WUSB/WBAN flows.

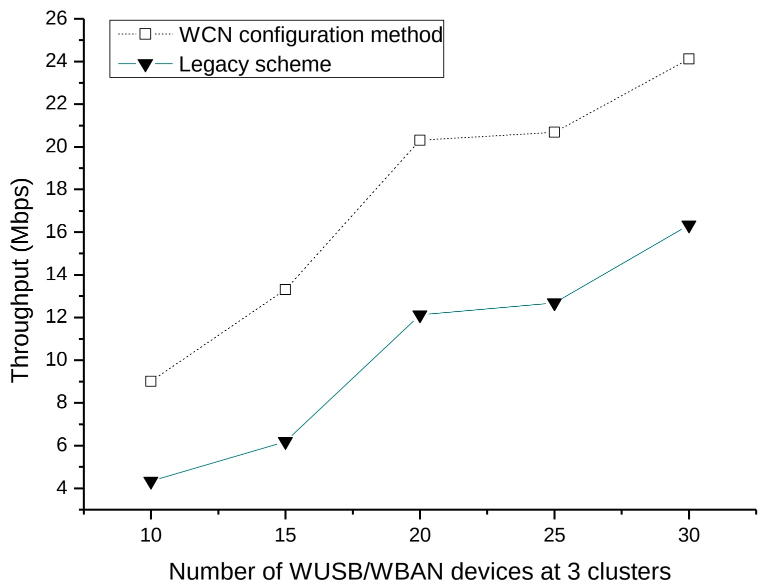

Figure 4. Throughput of Received WBAN Data Frames at Multiple Wearable Computer Networks

To analyze the performance of the multiple WCN configuration method, we used a number of average lost packets as a performance measure. As the number of hops increase, in the legacy scheme the average path interference increases largely so that the number of average lost packets is larger than the proposed WCN configuration method. But in the proposed WCN configuration method, it decreases irrespective of medical and non-medical WBAN services due to the collision-free WUSB/WBAN resource allocation by WiMedia D-MAC connectivity and DRD connections.

5. Conclusions

In this paper, a method for multi-hop network extension of WUSB over WBAN protocol is proposed. The multi-hop networks are set up through DRD function and its clustering method. Simulation results proved that the multi-hop network configuration supports efficiently medical and nonmedical multi-hop WBAN services in viewpoints of delivery success rate and multi-hop path interference.

References

[1] M. Patel, and J. Wang, "Applications, challenges, and prospective in emerging body area networking technologies, Wireless Communications," 17, 3, pp.80-88 **(2010)**.
[2] USB 2.0, USB-IF **(2010)**, http://www.usb.org/home/.
[3] WiMedia Alliance, http://www.wimedia.org/.

[4] Certified Wireless USB 1.1, USB-IF **(2010)**, http://www.usb.org/developers/wusb/.
[5] WiMedia MAC Release Spec. 1.5, Distributed Medium Access Control (MAC) for Wireless Networks, WiMedia Alliance **(2009)**, http://www.wimedia.org/ en/index/asp.
[6] J.-W. Kim, K. Hur, J.-S. Park and D.-S. Eom, "A distributed MAC design for data collision-free wireless USB home networks," IEEE Transaction on Consumer Electronics, vol. 55, no. 3, **(2009),** pp. 547-553.
[7] IEEE 802.15 WPAN Task Group 6 Body Area Networks (BAN), **(2010)**, http://www.ieee802.org/15/pub/TG6.html.
[8] H. Liu, H. Darabi, P. Banerjee and J. Liu, "Survey of Wireless Indoor Positioning Techniques and Systems", IEEE Transactions on SYSTEMS, MAN, AND CYBERNETICS—PART C: APPLICATIONS AND REVIEWS, vol. 37, no. 2, **(2007),** pp. 278-291.
[9] J. H. Han and D. K. Jeong, "Comparisons of error characteristics between TOA and TDOA positioning", IEEE Transactions on Aerospace and Electronic Systems, vol. 38, no. 4, **(2002),** pp.183-189.
[10] A. Varga, "The OMNeT++ Discrete Event Simulation System", European Simulation Multi-conference (ESM'2001) **(2001)** October 15-19; Barcelona, Spain
[11] W.-Y. Shin, "Performance Evaluation of Parallel Opportunistic Multihop Routing", Journal of Information and Communication Convergence Engineering, vol. 12, no. 3, **(2014),** pp. 135-139.

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