Multi-hop Wireless Body Area Network Design for WUSB support in Wireless Home Networks

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Abstract. The wireless universal serial bus (WUSB) connects personal computers (PCs) to their peripherals and the consumer-electronics (CE) in people’s living home networks. 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 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.

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

1 Introduction

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 host and WUSB devices for compatibility with USB 2.0 specifications, the wired USB applications are serviced directly [1-6].

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 Multiple Wearable Computer Network Configuration

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 [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, the hub may also improvise future polls or posts starting and ending in a MAP.

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.

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.

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. 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.

3 Performance Evaluation

We designed the multiple WCN and simulated it for performance evaluation with WBAN medical/non-medical service parameters and WiMedia PHY/MAC parameters shown [7-9]. 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.

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, each WUSB/WBAN host sets up clean WBAN channel for its WUSB/WBAN flows without interference from other WCN’s WUSB/WBAN flows.

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.
4 Conclusion

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. In the WUSB clustering method, a new DRD message format reserves 2-hop range private DRP (Distributed Reservation Protocol) resources. 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.

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