Personal Area Distance Computing Systems

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Abstract

In this Paper, we propose a Personal Area Distance Computing System (PADCS). The proposed PADCS is built on WUSB (Wireless USB) over WBAN (Wireless Body Area Networks) protocol. And the PADCS is based on synchronized sensor nodes consisting of a WBAN, and location measurement results can be transmitted to the context-aware server through WUSB over WBAN protocol. In the PADCS, a WUSB host calculates the position of a receiving sensor node by using the difference between the times at which the sensor node received different WBAN beacon frames sent from the WUSB host. Performance of the PADCS is evaluated through simulation results and is compared with the Active Bat system with regard to distance computing error and the computing rate. The results demonstrate that the proposed system is a promising and feasible system for personal area distance computing environment where all sensor nodes comprise peripherals of a wearable computer system.

Keywords: *Distance estimation, Ranging, Wearable Computer, Wireless USB, Wireless Body Area Networks (WBAN)*

1. Introduction

The term middleware refers to the software layer located between the OS and the application layer. Middleware can be further classified based on "sub-middleware" functionalities including time synchronization, location, battery power, and network functionalities. Middleware supports an interface called API for use as libraries for the application layer. At the middleware level, time synchronization between users, nodes, and servers is an important issue in wireless networks. Based on time synchronization, wireless nodes can avoid the duplication of the data of an event, and the networks can identify sequences of event data; every wireless node periodically transmits data to a sink node through wireless networks [1, 2]. The integration of small-size, low-cost, highly sensitive sensors and low-power inexpensive wireless communication radios brings wireless sensor networks into reality. Wireless sensor networks (WSNs) are composed of a set of planned or ad-hoc deployed sensors that are sensitive to their surrounding environments and capable of communicating with each other through their wireless channels.

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 [3]. 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. 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)[4-8].

Because WUSB provides high speed connection between host and devices for the compatibility with USB 2.0 specification and removes the cable among devices using the USB protocol, it can provide the better user convenience than wired USB applications. Wireless USB system consists of a WUSB host that creates and maintains the Wireless USB Channel and WUSB devices that is connected with WUSB host and is controlled their data communications by WUSB host. Also the data transmission between WUSB devices is delivered via WUSB host, as WUSB specification is compatible for wired USB specifications. Like this, WUSB network consists of a WUSB host and several WUSB devices and is referred to as a WUSB cluster [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. A WBAN provides long-term health monitoring of patients under their natural physiological states without constraining their normal activities. The WBAN can be used to develop a smart and affordable health care system, and it can handle functions including basic diagnostic procedures, supervision of a chronic condition, supervising recovery from a surgical procedure, and emergency events [9].

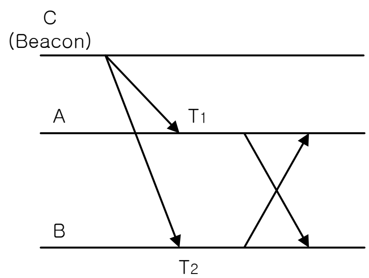
The context awareness and mobility support are major performance measures in the ubiquitous computing environment. To guarantee seamless mobility, research area of localization techniques had gotten large concerns. From that reason, Localization techniques such as Active Badge [10], Cricket [11], RADAR [12] were proposed. The GPS (Global Position System) is not adequate for the indoor environment. But, the above techniques provide indoor location information.

In this Paper, we propose a Personal Area Distance Computing System (PADCS). The proposed PADCS is built on WUSB (Wireless USB) over WBAN (Wireless Body Area Networks) protocol. And the PADCS is based on synchronized sensor nodes consisting of a WBAN, and location measurement results can be transmitted to the context-aware server through WUSB over WBAN protocol. In the PADCS, a WUSB host calculates the position of a receiving sensor node by using the difference between the times at which the sensor node received different WBAN beacon frames sent from the WUSB host. Performance of the PADCS is evaluated through simulation results and is compared with the Active Bat system with regard to distance computing error and the computing rate. The results demonstrate that the proposed system is a promising and feasible system for personal area distance computing environment where all sensor nodes comprise peripherals of a wearable computer system.

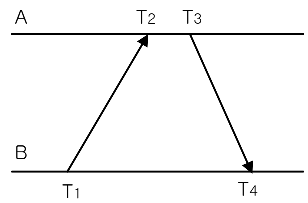
2. Basic Time-Synchronization Schemes

Many protocols have been reported for clock synchronization in WSNs, and these protocols all have some common basic approaches. Synchronization is achieved by exchanging clock (timestamp) information among nodes while reducing the effect of nondeterministic factors in message delivery. They can be classified into three types: receiver-receiver (R-R) synchronization, sender-receiver (S-R) synchronization, and one-way message dissemination [1].

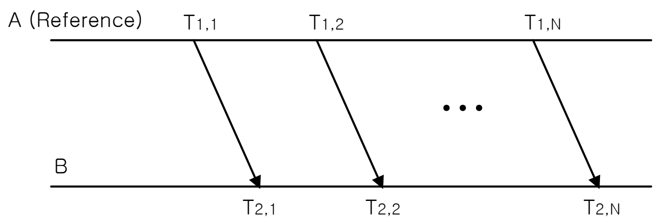
In R-R synchronization, a node periodically broadcasts wireless beacon messages to its neighbors. The receivers use the message's arrival time as a point of reference for comparing their clocks, and then exchange the local timestamps at which they received the same broadcast message, as shown in Figure 1(a). The receivers finally compute their offset based on the difference in reception times to synchronize their clocks. Reference Broadcast Synchronization (RBS) [2] is a typical R-R synchronization protocol.



(a) R-R synchronization



(b) S-R synchronization



(c) One-way message dissemination

Figure 1. Basic synchronization approaches

S-R synchronization is performed by a handshake protocol between a pair of nodes. Examples of synchronization protocols that employ this approach include Timing-sync Protocol for Sensor Networks (TPSN) [1], and Tiny-Sync and Mini-Sync (TS/MS) [2]. Figure 1(b) shows a two-way message exchange mechanism in TPSN protocol. Node B sends a message at its local time T_1, and Node A receives this packet at its local time T_2. At time T_3, Node A sends back an acknowledgment packet which contains the values of T_2 and T_3. After receiving the packet at T_4, Node B can calculate the clock offset (θ) and propagation delay (d) as (1). Knowing the offset, Node B can synchronize its clock to Node B's clock by adding θ to its current clock value.

$$\theta = \frac{(T_2 - T_1) - (T_4 - T_3)}{2}, \quad d = \frac{(T_2 - T_1) + (T_4 - T_3)}{2} \tag{1}$$

In one-way message dissemination, a reference node broadcasts its timing information to its neighbors, and they record the arrival times of the broadcast message, as shown in Figure 1(c). Collecting all the timestamps, each node can convert between the local hardware clock and the clock of the reference node by linear regression table. Flooding Time Synchronization Protocol (FTSP) [2] is a typical protocol utilizing one-way message dissemination scheme. After executing this time-sync protocol at each WBAN sensor node, in our PADCS, a WUSB host calculates the position of a receiving sensor node by using the difference between the times at which the sensor node received different WBAN beacon frames sent from the WUSB host.

3. WUSB over WBAN Protocol for Wearable Computing

WUSB defines a WUSB channel which is encapsulated within a WiMedia distributed MAC (D-MAC) superframe via private distributed reservation protocol (DRP) reservation blocks. The channel enables devices to reserve the medium to be addressed without contention. The WUSB channel is a continuous sequence of linked application-specific control packets, called micro-scheduled management commands (MMCs), which are transmitted by the WUSB host within the private DRP reservation blocks. Figure 2 shows the relationship between the WiMedia D-MAC and the WUSB protocol. 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 [6].

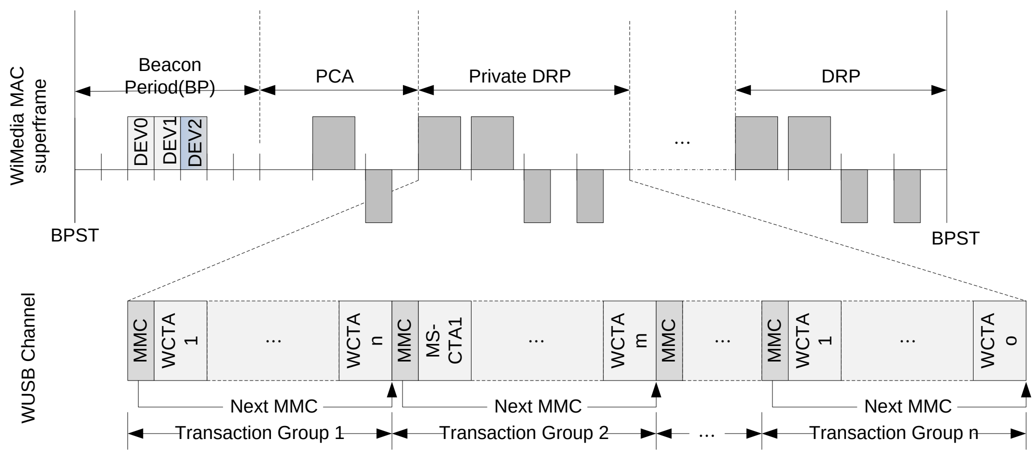


Figure 2. Example of data exchange between WUSB devices through WiMedia D-MAC

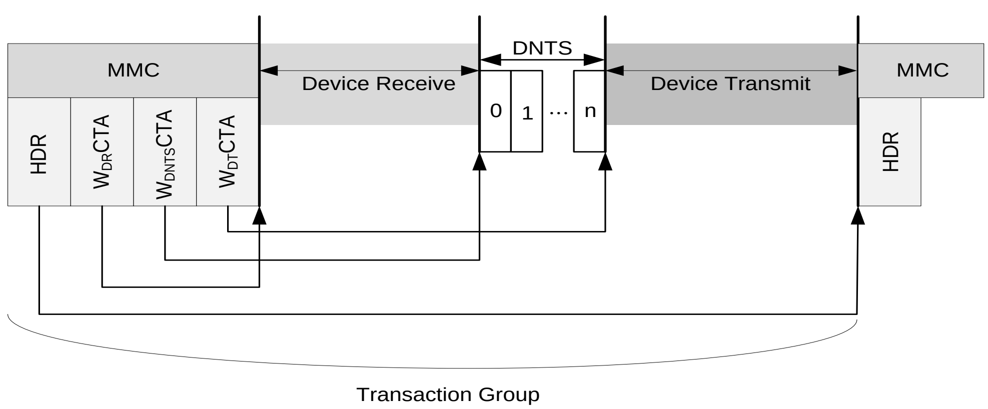


Figure 3. General structure of WUSB transaction group

Figure 3 shows the general model of a transaction group. The 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. The MMC is the fundamental element of the WUSB protocol. MMCs are used by a host to maintain and control the WUSB channel. The general structure of an MMC control packet is shown in Figure 4.

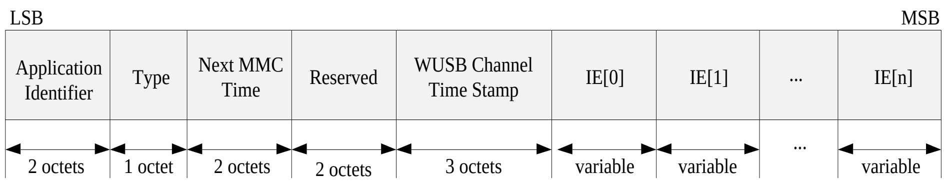
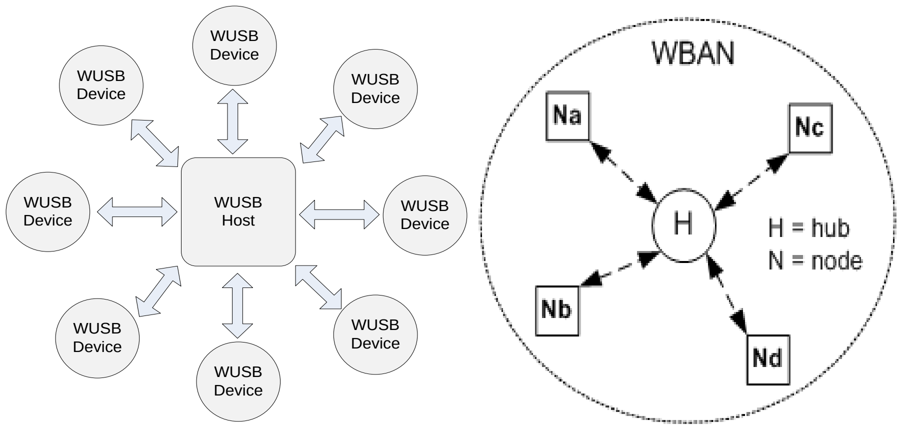


Figure 4. Format of MMC packet

The application identifier field in the MMC packet is set to indicate the WUSB (0100H). The type field is used to indicate the MMC command type, and it is set to 01H. The NextMMCTime field indicates the number of microseconds from the beginning of the current MMC packet to the beginning of the next MMC packet. The WUSB channel time stamp field is set to indicate the timestamp provided by the host based on a free running timer in the host. The value of this field is set to the clock value of the host when MMC transmission starts. The information element (IE) fields in an MMC are called WUSB channel IEs and they include protocol time-slot allocations, device notification time slots (DNTS), and host information [6].

MMCs are used to broadcast command and I/O control information to all devices belonging to the WUSB cluster. In addition, MMCs are used to advertise channel time allocations for point-to-point data communications between the host and the endpoints of the devices in the WUSB cluster. An MMC specifies the linked stream of wireless USB channel time allocation (WCTA) blocks up to the next MMC within the private DRP reservation block from or to the end of private DRP reservation block. If it is followed by another MMC without the existence of WCTAs between the two MMCs, the MMC is only used to convey command and control information. The channel time between two MMCs may also be idle time, where no WCTAs are scheduled. The direction of transmission and the use of each WCTA are fully declared in each MMC packet [6]. A WUSB network consists of a WUSB host and several WUSB devices, and this is referred to as a WUSB cluster [6]. Figure 5 shows the topology of a WUSB cluster. In a similar manner, IEEE 802.15.6 WBAN hubs and sensor nodes form a star topology [9].



(a) WUSB cluster. (b) WBAN cluster.

Figure 5. Topology of WUSB and WBAN clusters

Figure 6 shows the WUSB over WBAN architecture. Here, the 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 access 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 EAP2 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. In the Type-I/II access phase periods, the WBAN hub reserves time slots without contention to exchange data with its input-sensor nodes.

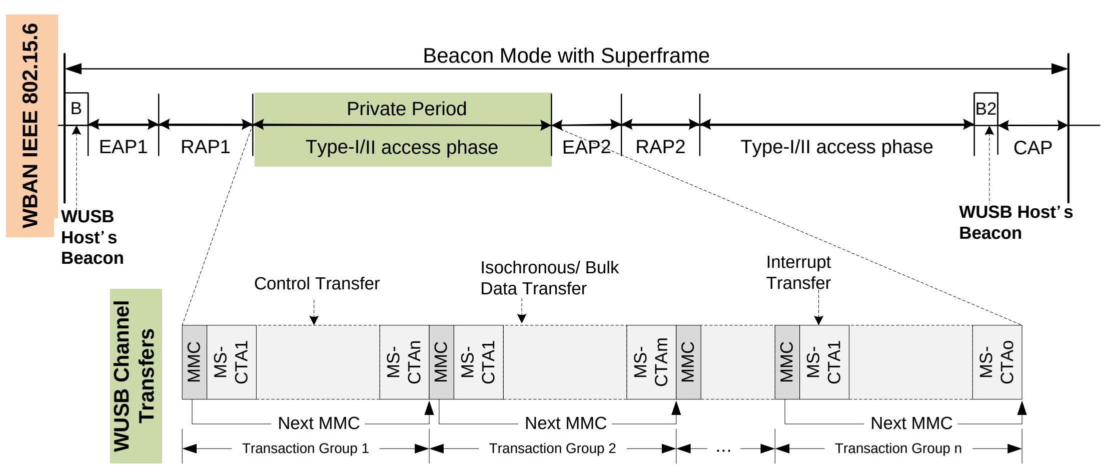


Figure 6. WUSB over WBAN architecture

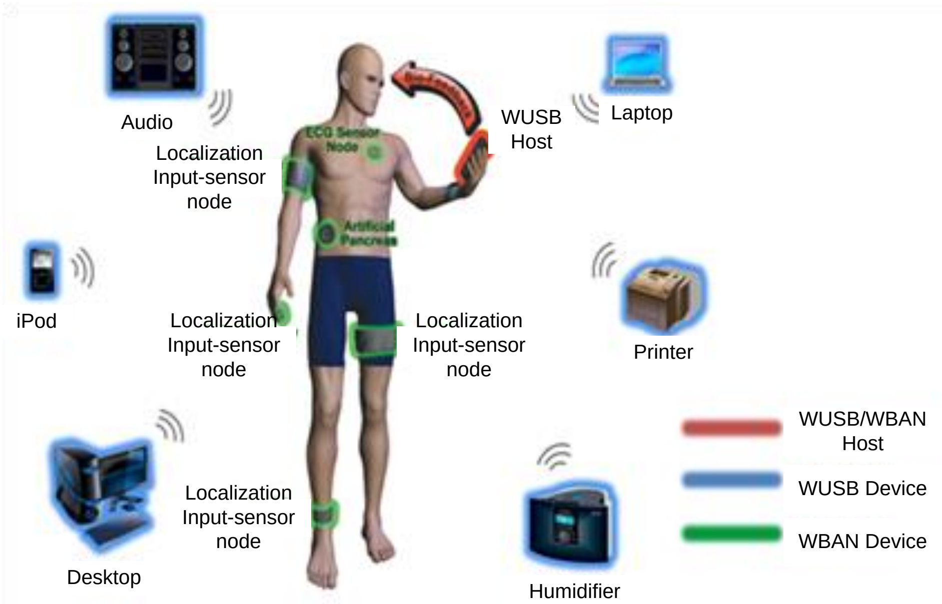


Figure 7. Wearable computer system using WUSB over WBAN architecture

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. Figure 7 shows the user scenario of a wearable computer system when using the WUSB over WBAN architecture. In this scenario, 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.

As shown in Figure 8 and Figure 9, the Wireless USB Channel Time Allocation information element (W_{CTA} IE) describes time slot allocation in Transaction Group and is included in a MMC packet [6]. Its general structure is showed in Figure 6.

LSB					MSB
bLength	IE Identifier (WCTA_IE)	W_XCTA[0]	W_XCTA[1]	···	W_XCTA[n]
1 octet	1 octet	variable	variable	···	variable

Figure 8. The format of WCTA IE

bLength field indicates the total length of the W_{CTA} IE, including bLength field. A W_{CTA} IE consists of one or more W_XCTA blocks. The W_XCTA block describes a time slot allocation relative to the MMC packet. There are several types of W_XCTA blocks and all W_XCTA blocks have a common header that includes an attribute field and time slot information for Transaction Group. The type of W_XCTA blocks is as follow: W_{DR}CTA (Device Receive), W_{DT}CTA (Device Transmit), W_{DNTS}CTA (Device Notification Time Slot). Figure 9 shows the format of WXCTA block common header.

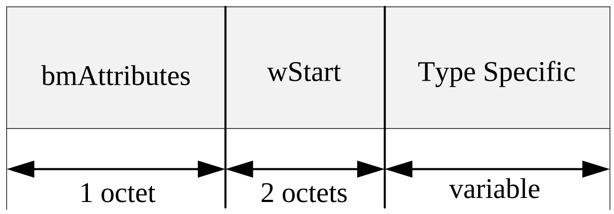


Figure 9. The format of W_XCTA block common header

Bits [7:6] of the bmAttributes field are W_XCTA Block Type Code and indicate the type of W_XCTA block. The value in bits [5:0] of the bmAttributes field is variable according to W_XCTA Block Type Code. Table 1 shows the interpretation of the W_XCTA according to the W_XCTA Block Type Code.

Table 1. The example for the interpretation of the WXCTA according to the W_XCTA

W_XCTA Block Type Code	Interpretation of Bits [5:0]
W_{DR}CTA (00B) or W_{DT}CTA (01B)	Bits [3:0] are the WUSB device endpoint number Bit [4] is dependent on W_XCTA type Bit [5] is a flag indicating that the time slot is associated with a SETUP stage of a control transfer.
W_{DNTS}CTA (10B)	Bits [5:0] are set to zero by the host and is ignored by devices
Reserved (11B)	N/A

The unit of wStart field is expressed in ms. The value in this field is expressed as an offset from the beginning of the MMC. The WUSB host always construct the IE so that they are ordered in time. Also, the IE is always constructed with any W_{DR}CTAs followed by a W_{DNTS}CTA and then by any W_{DT}CTAs for better channel utilization. Figure 10 shows the data flow in WUSB transaction.

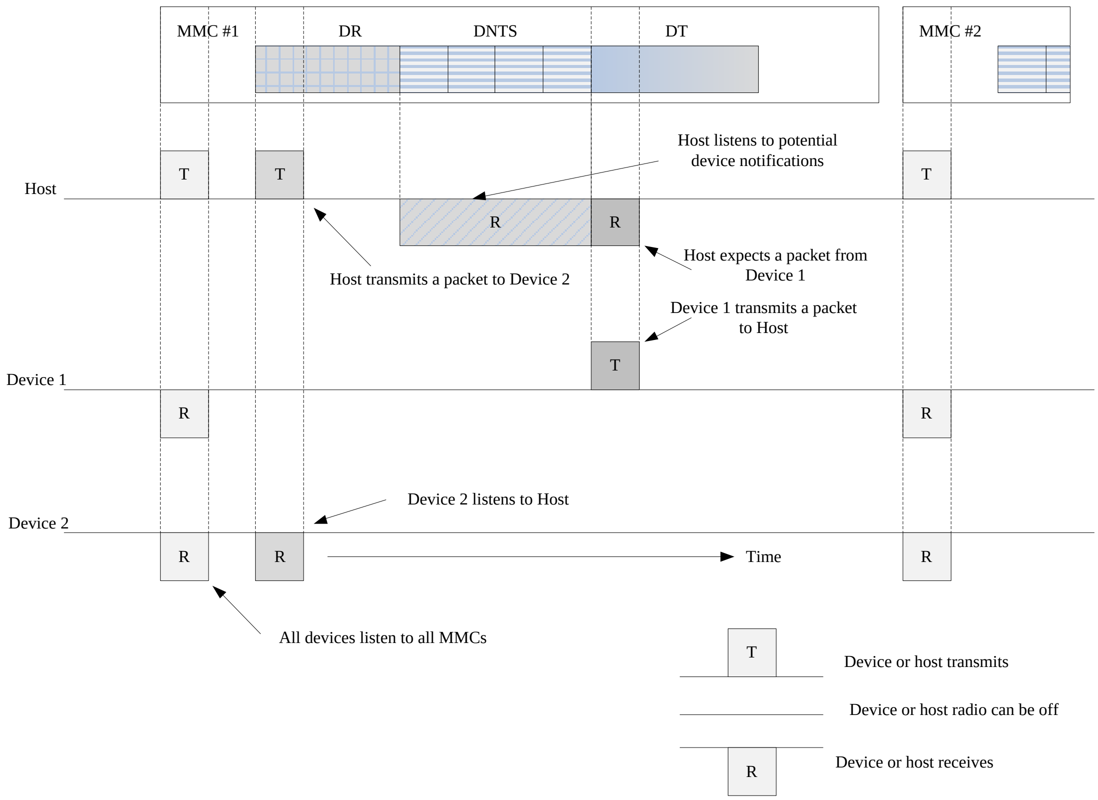


Figure 10. The data flow in WUSB Transaction Group

In Figure 10, WUSB host transmits the MMC packet to all WUSB devices belonging to its own WUSB cluster in MMC duration and data packets to the intended WUSB device Device 1 in W_{DR}CTAs blocks. Also, WUSB device Device1 transmits data packets to the WUSB host in W_{DT}CTAs duration.

4. Personal Area Distance Computing System Design

Active Badge and Active Bat [10] proposed passive ceiling-mounted receivers that obtain information from active transmitters carried by users. Active Badge uses infrared while Active Bat uses both radio frequency (RF) and ultrasound. In contrast, RADAR [12] uses 802.11 RF, and is not as accurate as the systems based on RF and ultrasound. However, RADAR does not require any infrastructure other than 802.11 access points. The Cricket [12] architecture can be taken as an inverse of the Active Badge and Active Bat systems in that ceiling- or wall-mounted active beacons send RF and ultrasound to passive receivers.

We have built a WUSB over WBAN for the workspace shown in Figure 7, where each WBAN beacon sends both an ultrasonic pulse and the RF message at the same time. The WBAN device (SLAVE) receiver uses the standard time difference of arrival technique by observing the time lag between the arrival of the RF and ultrasonic signals, and estimates its distance from each WBAN host's beacon. The estimated distances are passed to the context-aware WUSB application server, which computes the location of the WBAN device receiver using the distances.

Our PADCS system is different from Cricket [11] in that the receiver is separated from the WBAN host. The receiver can then send context information to an authenticated server looking for a specific service. In the current proof-of-concept implementation, WUSB application service is requested by providing the WUSB/WBAN host with the user's location information. We have developed an ultrasonic WBAN sensor module with a pair of transmitter and receiver. The ultrasonic sensor module is plugged into the main node. The main node consists of the 8-bit AVR MCU, a mobile transceiver of 2.4GHz ISM bandwidth, 128KB memory, etc.

The wireless WBAN sensor nodes are used for both the WBAN beacon node and for the WBAN receiver node. The light-weight WBAN beacon nodes are easy to deploy. They can be placed with few constraints in an body environment. The light-weight WBAN receiver node can be easily attached to a physical object. In the current experiments, the WBAN receiver node communicates with the WBAN application server through serial communication, but can be seamlessly replaced by RF communication.

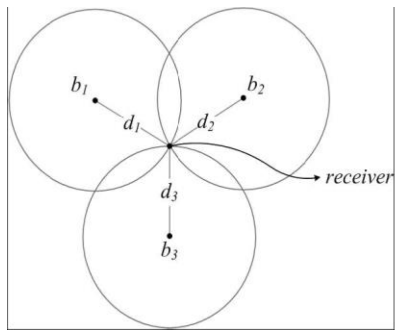


Figure 11. Trilateration

The context-aware WBAN application server computes the location (x, y, z) of the WBAN receiver using the distances through the trilateration method, as illustrated in Figure 11. Suppose the location of the i-th WBAN beacon is denoted by bi, and the estimated distance between the i-th beacon and the WBAN receiver is di. Then, we have the following equation for a beacon:

$$(x-b_{ix})^2+(y-b_{iy})^2+(z-b_{iz})^2=d_i{}^2 \qquad (1)$$

The above equation is solved using Newton-Raphson method. In the current implementation, the initial location (x0, y0, z0) of the WBAN receiver is set to the center of the workspace. Figure 12 describes the modularized frameworks for location-aware application service using WUSB-based WBAN protocol. In addition to the modules for computing and transferring location data (LCM and LTM), the location-aware framework includes Virtual Location Module (VLM), which makes the WUSB application development process independent of the WBAN sensor network. Even with the WBAN sensor network disabled, location-aware application can be tested by running VLM, which takes mouse input in the current implementation. The two frameworks communicate with each other through WBAN.

The location data are passed to Location Receiver Module (LRM) of the WUSB application Framework, and then to an Input Transformation Module (ITM). ITM is responsible for processing the location data to be suitable for specific applications. Many 3D applications can benefit from such pose-awareness.

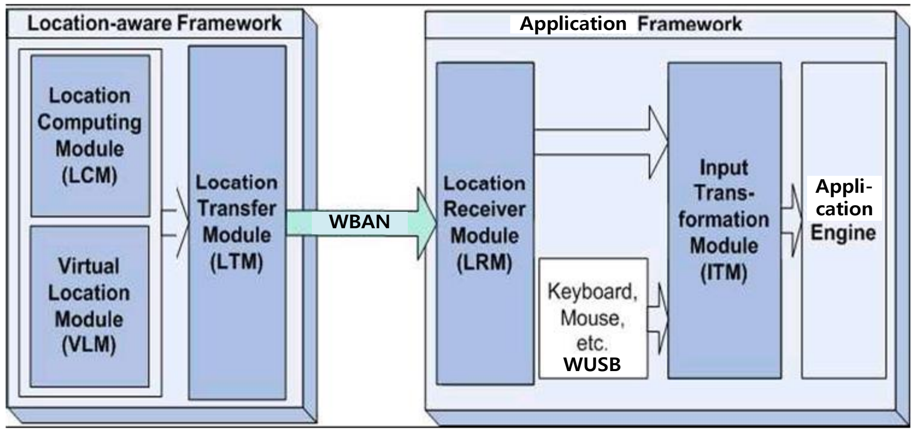


Figure 12. Location-aware WUSB over WBAN Platform framework

5. Performance Evaluation

The distances between the WBAN beacon nodes and the WBAN receiver node are obtained in an asynchronous mode [13-17]. The main WBAN beacon node uses a 16-bit timer, and the location of the WBAN receiver is computed at 10Hz. Both of the Location-aware application Frameworks are coded in C++, and run in 1.4GHz core i5 CPU and 2G RAM. The accuracy of the distance estimation has been tested [13-17]. For a fixed position of the WBAN receiver, the distance from a WBAN beacon is measured by hand. Then, the distance is estimated in the proposed framework. Such estimation is done for 2,000 times. Table 2, Table 3 and Figure 13 show the statistics for the measured distances of 49.65cm. This distance test proves that the WBAN can be successfully integrated with WUSB applications.

Table 2. Estimated distances at at 49.65cm

Distance (cm)	Frequency (2000 times in total)
49.569	67
49.604	465
49.638	987
49.709	481

Table 3. Statistical Analysis at 49.65cm

Statistics	Value
mean	49.644859 cm
variance	0.002045 cm
standard deviation	0.045221 cm

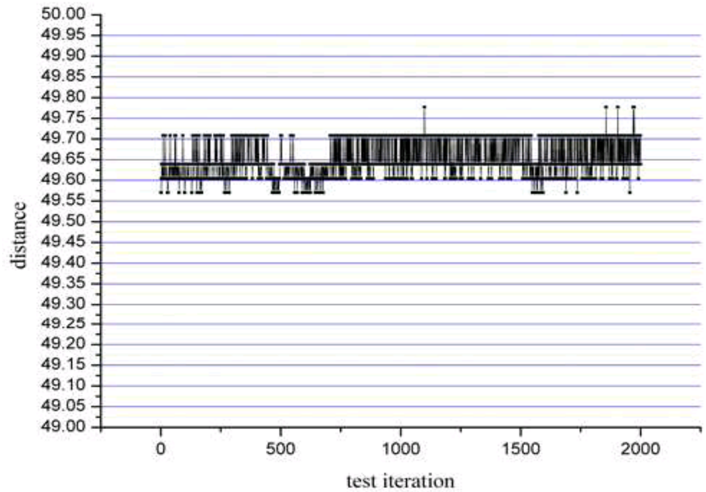


Figure 13. Test Results at 49.65cm

Table 4 presents the results of measuring distance between a WBAN beacon node and receiver facing each other. The real distances between two nodes are set to 50 cm and 100 cm. For each case, the distance between two nodes has been measured 1000 times.

Table 4. Accuracy of distance measurement

Actual distance measurement	Mean	Standard deviation
50 cm	49.64515 cm	0.0008710
100 cm	100.0541 cm	0.0009167

Experiments for measuring location error were performed. In the experiments, the location error of receiver has been measured, while placing the receiver at various positions in a zone. The location error is defined as the Euclidean distance between the position of the receiver and the position estimated by the our location system. For comparing our middleware with Active Bat system, in addition, we measured the location error in the same system with Active Bat beacon node and listener. Table 5 presents a comparison of the location error observed for both localization systems.

Table 5. Comparison of the location error

System	Proposed			Active Bat		
Location of receiver	*Center*	*Border*	*Average*	*Center*	*Border*	*Average*
Average location error (cm)	*0.828*	*1.585*	*1.015*	*0.934*	*1.914*	*1.235*

It can be shown that both systems provide similar average location error. The tendency that location error was found to become larger in the boundary of the zone, however, depending on the location of receiver, the distance error is not changed. It is assumed that the cause of this problem comes from the trilateration technique using the Newton-Raphson method since the distance error does not depend on the location of the receiver. The distance error is intentionally introduced when using the trilateration technique and the location error for the receiver is compared on the center of the zone and on the border of the zone.

In order to conduct the stable performance test of the context-aware application, the iterative tests with error measurement were conducted. Table 6 and Table 7 present the location error when ±0.6 and ±1.0 distance error is intentionally introduced for the two cases.

Table 6. The location error on the center of zone and on the center of test zone

Distance error (cm)	Received WBAN Beacon number for three beacons	Location error (cm)	Distance error (cm)	Beacons with distance error	Location error (cm)
+0.6	1, 2, 3	*0.00*	*-0.6*	1, 2, 3	*0.00*
	1, 3	*0.53*		1, 3	*1.72*
	1, 2	*0.53*		1, 2	*1.72*
	2, 3	*0.74*		2, 3	*2.42*
	1	*0.74*		1	*2.42*
	2	*0.51*		2	*1.72*
	3	*0.51*		3	*1.72*
+1.0	1, 2, 3	*0.00*	*-1.0*	1, 2, 3	*0.00*
	1, 3	*0.85*		1, 3	*1.71*
	1, 2	*0.85*		1, 2	*1.71*
	2, 3	*0.72*		2, 3	*2.42*
	1	*0.72*		1	*2.42*
	2	*0.51*		2	*1.71*
	3	*0.51*		3	*1.71*

Table 7. The location error on the center of zone and on the border of zone

Distance error (cm)	Received WBAN Beacon number for three beacons	Location error (cm)	Distance error (cm)	Beacons with distance error	Location error (cm)
+0.6	1, 2, 3	*0.30*	*-0.6*	1, 2, 3	*0.30*
	1, 3	*0.87*		1, 3	*1.91*
	1, 2	*0.86*		1, 2	*1.45*
	2, 3	*1.21*		2, 3	*2.36*
	1	*1.21*		1	*2.36*
	2	*1.03*		2	*1.91*
	3	*0.61*		3	*1.41*
+1.0	1, 2, 3	*0.51*	*-1.0*	1, 2, 3	*0.51*
	1, 3	*1.46*		1, 3	*3.30*
	1, 2	*2.01*		1, 2	*2.42*
	2, 3	*2.01*		2, 3	*3.95*
	1	*2.01*		1	*3.95*
	2	*1.72*		2	*3.16*
	3	*1.01*		3	*2.42*

As presented in the tables, although same distance measurement error is introduced in the two cases, the trilateration technique using numerical analysis fails to provide the same location error. The location error can be 3.95 cm on the zone when the distance error is -1.0 cm. The reason that location error becomes larger in the boundary of the zone is not to be discussed, because this topic is beyond the scope of this paper. It is important to note that location error of the system is less than 2.42 cm, regardless of the location of the receiver in the test zone.

6. Conclusion

In this paper, we propose a Personal Area Distance Computing System (PADCS) Built on WUSB over IEEE 802.15.6 WBAN protocol required for Wearable Computer systems. The implementation results prove that PADCS can be well integrated, and lead to a new type of natural interface for the Wearable Computer systems. In the current implementation, the location data are computed at 10Hz. For fully supporting real-time applications, more effort should be made to increase its performances. Further, many applications may benefit not only from location-awareness but also from orientation-awareness. To fulfill such needs, the overall performances should be continuously upgraded.

Acknowledgements

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References

[1] S. Ganeriwal and M. Srivastava, “Timing-sync Protocol for Sensor Networks”, Proceedings of ACM Sensys, **(2003)** November 14-18, Los Angeles, USA.
[2] H. Dai and R. Han, “TSync, A Lighweight Bidirectional Time Synchronization Service for Wireless Sensor Networks”, Proceedings of ACM SIGMOBILE Mobile Computing and Communication, **(2004)** April 18-21, Dallas, USA.
[3] R. Rosenberg and M. Slater, “The Chording Glove: A Glove-Based Text Input Device”, IEEE Transaction on Systems, Man, and Cybernetics-Part C: Applications and Review, vol. 29, no. 2, **(2009)**.
[4] USB 2.0, USB-IF, http://www.usb.org/home/.
[5] WiMedia Alliance, http://www.wimedia.org/.
[6] Certified Wireless USB 1.1, USB-IF **(2010)**, http://www.usb.org/developers/wusb/.
[7] WiMedia MAC Release Spec. 1.5, “Distributed Medium Access Control (MAC) for Wireless Networks”, WiMedia Alliance **(2009)**, http://www.wimedia.org/en/index/asp.
[8] K. -I. Kim, “Adjusting Transmission Power for Real-Time Communications in Wireless Sensor Networks”, Journal of Information and Communication Convergence Engineering, vol. 10, no. 1, **(2012)**.
[9] IEEE 802.15 WPAN Task Group 6 Body Area Networks (BAN), IEEE, **(2010)**, http://www.ieee802.org/15/pub/TG6.html.
[10] R. Want, A. Hopper, V. Falcao and J. Gibbons, “The Active Badge Location System”, ACM Transactions on Information Systems, vol. 10, no. 1, **(1992)**, pp. 91-102.
[11] N. Priyantha, A. Chakraborty and H. Balakrishnan, “The Cricket Location-Support System”, Proc. of 6th ACM MOBICOM, **(2000)**, pp. 342-350.
[12] P. Bahl and V. Padmanabhan, “RADAR: An In-Building RF-based User Location and Tracking System”, Proc. of IEEE INFOCOM, **(2000)**, pp.145-153.
[13] S. -R. Kim, D. -Y. Lee and C. -W. Lee, “An Adaptive MAC Scheduling Algorithm for Guaranteed QoS in IEEE 802.11e HCCA”, International Journal of Future Generation Communication and Networking, vol. 1, no. 1, **(2008)**.
[14] A. Nandi and S. Kundu, “Energy Level Performance of Packet Delivery Schemes in Wireless Sensor Networks over Fading Channels”, International Journal of Future Generation Communication and Networking, vol. 4, no. 2, **(2011)**.

[15] N. Karthikeyan, V. Palanisamy and K. Duraiswamy, "Performance Comparison of Broadcasting methods in Mobile Ad Hoc Network", International Journal of Future Generation Communication and Networking, vol. 2, no. 2, **(2009)**.
[16] M. Mana, M. Feham and B. A. Bensaber, "SEKEBAN (Secure and Efficient Key Exchange for wireless Body Area Network)", International Journal of Advanced Science and Technology, vol. 12, **(2009)**.
[17] G. Min and M. I. Abu-Tair, "Design and Evaluation of a Medium Access Control Scheme in Wireless Local Area Home Networks", International Journal of Smart Home, vol. 2, no. 1, **(2008)**.

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