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A Multimedia Streaming Scheme for N-Screen Services in Wearable Sensor-Based Systems for Health Monitoring

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Abstract

A hierarchical system of wireless USB (WUSB) over wireless body area networks (WBAN) is adopted for wearable health-monitoring systems (WHMS). It is executed on the basis of WUSB over WBAN protocol at each wearable sensor node comprising the WHMS. Basically, a single WHMS operates based on WUSB over WBAN protocol. And the multiple WHMSs operate based on the WiMedia D-MAC protocol and dual-role device (DRD) function. In this paper, a multimedia streaming scheme for N-screen services is proposed for WHMS networks. In a hospital, N-screen applications must be required by using WHMS networks. The multimedia streaming scheme for N-screen services is composed of service interval-based resource allocation and multicast reservation schemes. In simulation results, efficiency of the multimedia streaming scheme is proven through throughput and delay performances at an N-screen service scenario.

Keywords: *Bio-informatics, Body Sensor Networks, IEEE 802.15.6, N-screen, U-health services*

1. Introduction

Wearable health-monitoring systems (WHMS) may comprise various types of miniature sensors, wearable or even implantable [1, 2]. These biosensors are capable of measuring significant physiological parameters like heart rate, blood pressure, body and skin temperature, oxygen saturation, respiration rate, electrocardiogram, and so forth. The obtained measurements are communicated either via a wireless or a wired link to a central node, for example, a personal digital assistant (PDA) or a microcontroller board, which may then in turn display the according information on a user interface or transmit the aggregated vital signs to a medical center. The previous illustrates the fact that 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.

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

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use the wireless universal serial bus (WUSB) that refers to USB technology that is merged with WiMedia Distributed MAC (D-MAC) technical specifications [3-5]. 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. 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 [6].

N-screen is an emerging technology and demand of future to support multimedia multicasting, content sharing, content mobility, media scalability, media synchronization, and seamless mobility. In recent years, as various kinds of smart devices such as smart phones are emerging, and the subject of communication such as M2M (Machine-to-Machine) have expanded, services that target various devices reborn as a new convergence services through a continuing evolution [7, 8]. N-screen service transmits the service content via a wired or wireless network. Since the increase of the requirement for high quality image service causes the increase of network bandwidth required for service, the technology for the efficient use of network resource is essential. Thus, the service providers should obtain the technology that uses service network efficiently and the technology that provides the highest quality content seamlessly.

A hierarchical system of wireless USB (WUSB) over wireless body area networks (WBAN) is adopted for wearable health-monitoring systems (WHMS). It is executed on the basis of WUSB over WBAN protocol at each wearable sensor node comprising the WHMS. Basically, a single WHMS operates based on WUSB over WBAN protocol. And the multiple WHMSs operate based on the WiMedia D-MAC protocol and dual-role device (DRD) function. In this paper, a multimedia streaming scheme for N-screen services is proposed for WHMS networks. In a hospital, N-screen applications must be required by using WHMS networks. The multimedia streaming scheme for N-screen services is composed of service interval-based resource allocation and multicast reservation schemes.

2. Related Works

P2P streaming technology is mainly used as the technology that uses service network efficiently, and adaptive streaming technology is mainly used as the technology that ensures seamless video streaming. As shown in Figure 1, P2P streaming is not the technology that receives service content from server, but the technology that receives service content from close client. P2P streaming technology has the disadvantage that it uses the resource of user's device and network, but it has the advantage that provides a better quality of service by reducing the server load and network costs. In addition, because the most P2P streaming technology measures user's resource in advance, users do not interfere with the use of their devices [7, 8].

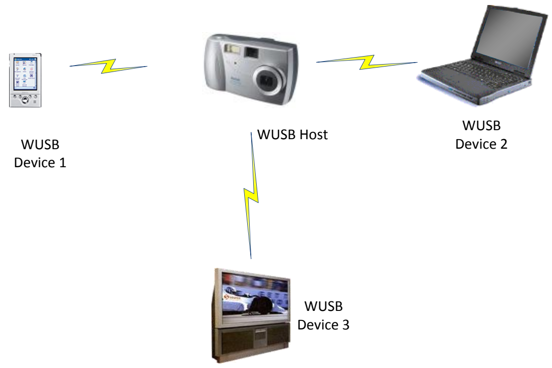

Figure 1. P2P N-screen Service using Wireless USB Systems

Adaptive streaming technology checks the service environment such as available network bandwidth, the performance of the equipment, *etc.*, and is the technology that transmits variable quality of image data to enable to provide a seamless service. For example, if a user with a high-performance device is in a good network environment, user's device transmits high definition content. Otherwise low quality content is transmitted. This P2P N-screen service can be realized in a WPAN environment by using the WUSB system as in Figure 1.

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 [6].

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 Figure 1, the hub may also improvise future polls or posts starting and ending in a MAP.

Figure 2 shows the WUSB over WBAN architecture for single WHMS. In the WUSB over WBAN Architecture, in order to set up a wireless communication link to WHMS, 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 a scheduling.

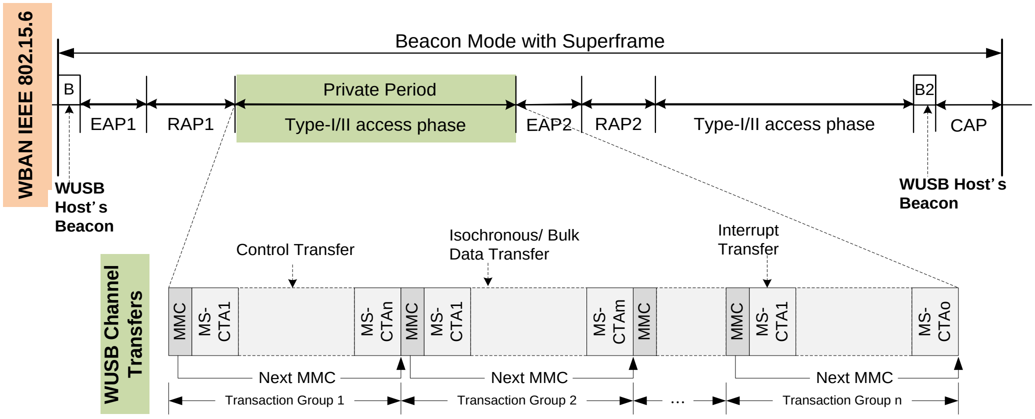

Figure 2. WUSB over WBAN Architecture

Figure 3 shows the user scenario of a WHMS 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 input interfaces for WHMS 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.

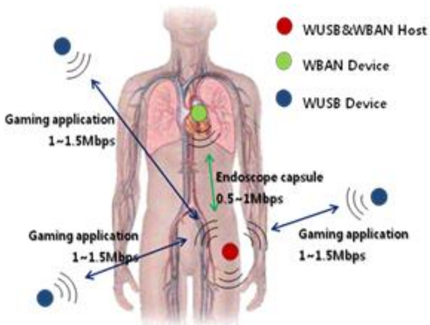

Figure 3. Single WHMS using WUSB over WBAN Architecture

3. WHMS Network Configuration

WUSB allows a dual role device (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 [3]. 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 [3], 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 4, a WUSB cluster tree topology is formed to configure WHMS networks. Basically, a single WHMS 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 WHMSs are manipulated in a time period during a WiMedia D-MAC superframe, as shown in Figure 5. By adopting the D-MAC, our WHMS solves the simultaneously operating piconet (SOP) problem in the centralized IEEE 802.15.3 MAC. In the D-MAC, each node broadcasts its own beacon containing IEs per 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 WHMS 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 WHMSs can be constructed.

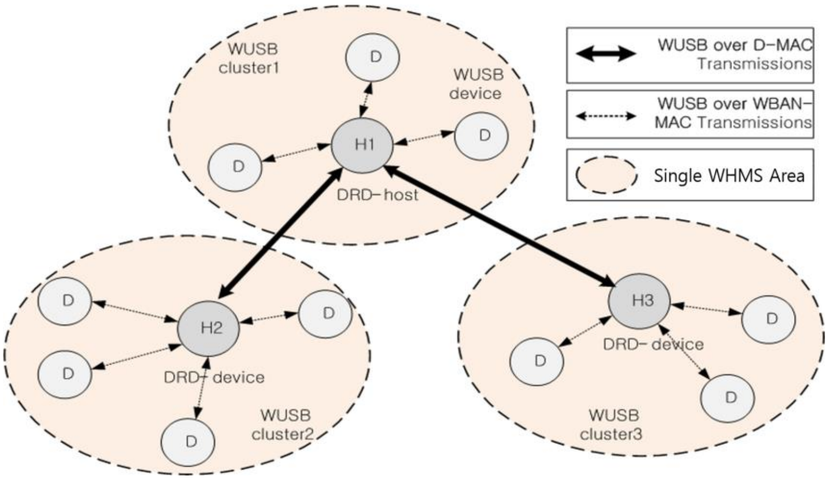

Figure 4. A WUSB Cluster Tree Topology for Multiple WHMS Networks

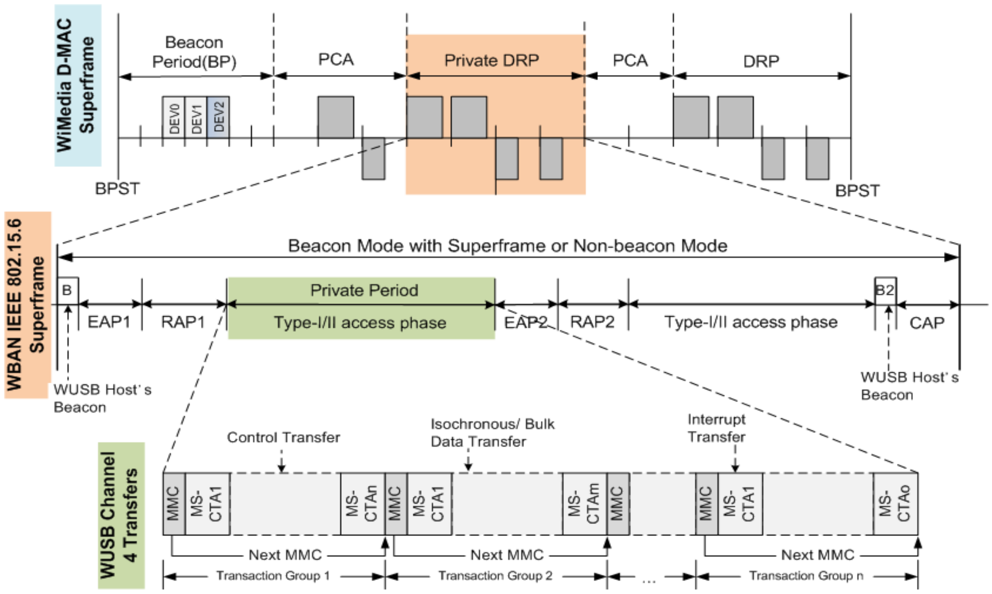

Figure 5. WUSB and DRD Time Flows Allocated for Multiple WHMS Networks

4. Multimedia Streaming Scheme for N-screen Services

In this paper, a multimedia streaming scheme for N-screen services is proposed for WHMS networks. In a hospital, N-screen applications must be required by using WHMS networks. The multimedia streaming scheme for N-screen services is composed of service interval-based resource allocation and multicast reservation schemes. Furthermore, to provide the OSMU (One Source Multi Use) N-screen service through P2P streaming in the seamless D-MAC protocol, a new N-screen DRP Availability IE is proposed. In this N-screen DRP Availability IE, new fields for indicating Multicast DRP Owner and Receiver are required. The ACK frame transmissions are not required for Multicast transmissions in P2P N-screen services. Using this property, the N-screen DRP Availability IE scheme is proposed to expand the number of time slots available for multicast N-screen distributed reservation protocol (DRP) reservations as shown in Figure 6.

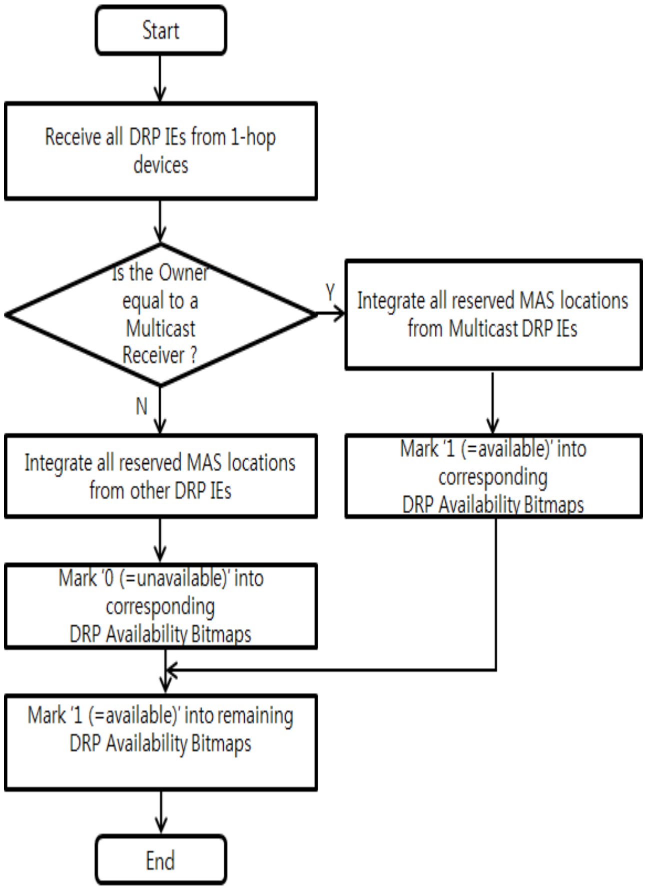

Figure 6. Generation Procedure of N-screen DRP Availability IE

In the WHMS networks, making a reservation of network resources using the WiMedia D-MAC distributed reservation protocol (DRP) requires determining the number of Medium Access Slots (MASs) and locations of MASs within WiMedia superframe. The number of MASs per superframe depends on many factors such as traffic source bandwidth characteristics, PHY transmission data rate, link condition and/or transmission distance, MSDU sizes, and acknowledgement type. The locations of the MASs within a superframe depend on the total number of MASs, service interval or latency requirement, traffic source burst feature. In addition, both the total number and the locations of MASs are constrained by MAC reservation policies [4]. Derivation of DRP reservation for an N-screen multimedia application using a WHMS Vital Video (WVV) is used to demonstrate relevant MAC reservation policies and to illustrate the trade-off between service interval and reservation bandwidth that is also referred to as service rate.

Consider a multimedia application with a WVV stream and a WHMS video recorder (WVR) recording the same program. At some point, the user picks up a remote control and tunes the set-top box (STB) to start the WVV program. The WVR in the STB simultaneously starts to record the same program to a wirelessly connected external hard disk drive that is located in a closet next to the operating room. Assume the video source of the WVV generates an MPEG 4 elementary stream using Real-time Transport Protocol (RTP) as transport, and the token bucket TSPEC of the WVV stream are Mean Data Rate r (= 4.13 Mbps), Peak Data Rate p (= 14.8 Mbps), Maximum Burst Size b (= 131350 octets), Maximum packet size M (= 1490 octets), Minimum policed unit m (= 49 octets), Nominal packet size (= 1427 octets) and Maximum Delay Constraint d_s (= 64 ms). In this example, there are two identical streams transmitted on the medium. Therefore there are two DRP reservations, referred to as STB and WVR.

MAC reservation policies concern both reservation limits and reservation locations. MAC policies regarding reservation limits include restrictions on the total medium time in units of number of MASs, and on reservation block sizes. Block size limits depend on the location of the block within an allocation zone. The permissible maximum block size of any safe reservation is 8 MASs. Safe blocks larger than 4 MASs are restricted to the first 8 MASs of each allocation zone. Allocation zones of a WiMedia superframe excluding allocation zone zero are further grouped into 4 subsets of allocation zones, called isozones, as depicted in Figure 7. Each isozone is identified by its index, called iso-index, ranged from 0 through 4.

MASs within an isozone are distributed evenly across the superframe. More specifically, the MASs located in the same row and "adjacent" allocation zones within an isozone are separated from each other by a uniform interval that depends on the isozone in which the MASs are located. Such an interval is referred to as the native service interval of the isozone.

Table 1 lists the native service interval, and comprising allocation zones of each isozone. Notice that higher-indexed isozones are capable of supporting smaller service interval, hence tighter delay bound. In order to make room for subsequent reservations that may request smaller service interval or tighter delay bound, MAC polices on reservation locations require the selection of reservation blocks in the isozones with as low iso-indices as possible, provided the locations meet the application's latency requirement.

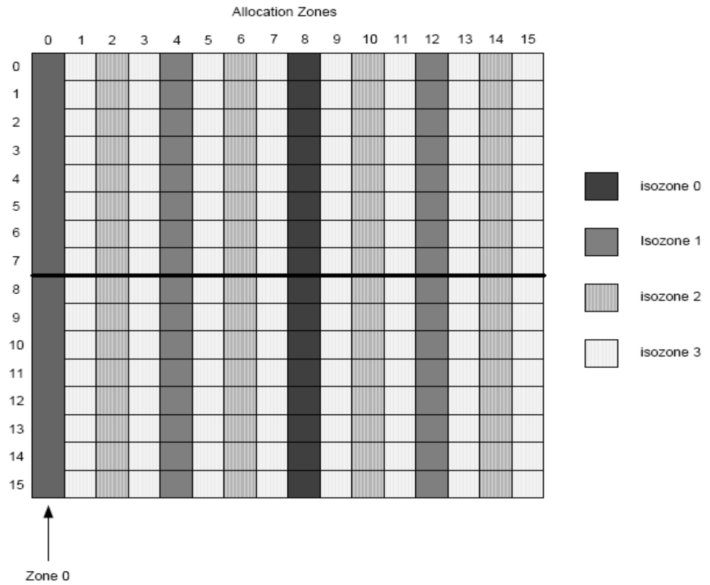

Figure 7. Isozone Structure in 2D View of a WHMS WiMedia Superframe

Table 1. Native Service Intervals of Isozones

Isozone Index	Number of allocation zones (p)	Comprising allocation zones	Native service interval (milliseconds)
0	1	8	16 x 4.096
1	2	4, 12	8 x 4.096
2	4	2, 6, 10, 14	4 x 4.096
3	8	1, 3, 5, 7, 9, 11, 13, 15	2 x 4.096
4	15	All	4.096

Service interval (SI) of a reservation is tightly dependent on the number of allocation zones per superframe, which a reservation occupies. The number is referred as value p as listed in Table 1. Therefore, the p value is first determined based on the block size and consequently *SI* is determined based on the value of p [4]. If both the set-top box and WVR transmit the video stream at a PHY data rate of 106.7 Mb/s, we assume that the service rate of approximately 10Mbps to transmit such a WHMS N-screen stream would require roughly 40 MASs per superframe.

The maximum block size for a safe reservation is 8 MASs. Hence the lower bound on the number of allocation zones needed for each reservation is p_{min}, equal to 5 (=40/8). Upper bound of p is when the reservation occupies every allocation zones excluding allocation zone zero. Therefore the maximum p_{max} is 15. Therefore, the p value should be chosen in the range [5, 15]. As seen in Table 1, the higher p, the higher iso-index. In addition, the higher the p value, the smaller the block size becomes, given a fixed total number of MASs.

If p is chosen as the upper bound of 15, the resulting reservation would be located in the “virtual” isozone 4 with the highest iso-index. MAC policies on reservation locations require to allocate in as low-indexed isozone as possible. If p is chosen to be 5, STB reservation would occupy isozone 2 (2, 6, 10, 14 zones) and allocation zone 8 including MASs from 0 to 7. The corresponding maximum service interval is 16.384 ms (=4 x 4.096ms). This consequently determines the upper bound of queuing delay d_q and corresponding required reservation bandwidth g5 b as in Eq.(1). As seen from Table 1, choosing a larger value of p, or smaller value of *SI*, allows for larger queuing delay d_q, which results in less reservation bandwidth g as indicated in Eq.(1) [4].

$$d_q = 64 - 16.384 = 47.616\ ms$$
$$g_5 = \frac{p}{1 + d_q \cdot \frac{p-r}{b}} = \frac{14.8}{1 + 0.047616 \cdot \frac{14.8 - 4.13}{0.13135 \cdot 8}} = 9.98\ Mbps \qquad (1)$$

5. Experiments

We designed the multiple WHMS network and simulated it for performance evaluation with WBAN medical/non-medical service parameters and WiMedia PHY/MAC parameters as in Tables 2, 3 and 4 [3-10]. In the simulation, the single WHMS network size is 2.5m*2.5m and three WHMSs are connected through the D-MAC and DRD functions. One WUSB/WBAN host and four WUSB/WBAN bio-sensor devices with CCA function turned on are deployed into each WHMS. WBAN frame size is fixed to 4095 bytes.

Table 2. 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 3. 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 4. WiMedia PHY/MAC Parameters

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

To evaluate performance of a multimedia streaming scheme for N-screen services proposed in WHMS networks, we conducted the simulations with a WHMS host broadcasting scenario. In the simulations, the WHMS host device always transmits multimedia data to neighbor clients. The results are averaged over 500 simulation runs. The parameters used in the simulation are shown in Table 5 [6-13]. In this simulation, the data rate of host and device 106.6Mbps.

Also, we consider a multimedia application with a WHMS Vital Video (WVV) stream and a WHMS video recorder (WVR) recording the same program. At some point, the user tunes the set-top box (STB) to start the WVV program. The WVR in the STB simultaneously starts to record the same program to a wirelessly connected external hard disk drive that is located in a closet next to the operating room. Assume the WVV source generates an MPEG-4 stream using Real-Time Transport Protocol (RTP) as transport, and Table 6 shows the token bucket TSPEC of the WVV stream [6-8].

Table 5. Simulation Parameters

Parameter	Value
Frame Size	4096 Bytes
Basic Data Rate	53.3Mbps
Bandwidth	528Mhz
Symbol Length	312.5ns
Preamble Length	9.375us
Header Length	3.75us
SIFS	10us
MISF	1.875us
Transmission Power	-41.3dB/Mhz

Table 6. Token Bucket TSPEC of WVV Traffic Streams

Mean Data Rate	4.13 Mbps
Peak Data Rate	14.8 Mbps
Maximum Burst Size	131350 bytes
Maximum Packet Size	1490bytes
Maximum allowable delay	64ms

In Figure 8, WVV throughput of WHMS device using the proposed WHMS system does not change regardless of the number of WHMS clients. This is because WHMS host can multicast larger multimedia WVV data to the adjacent devices using the proposed N-screen DRP Availability IE. On the other hand, as the number of WHMS clients increases, the throughput of WHMS devices using the legacy system gradually decreases since the legacy WHMS protocol only supports the communications without the service interval-based multicast-free connections between the WHMS host and the WHMS devices.

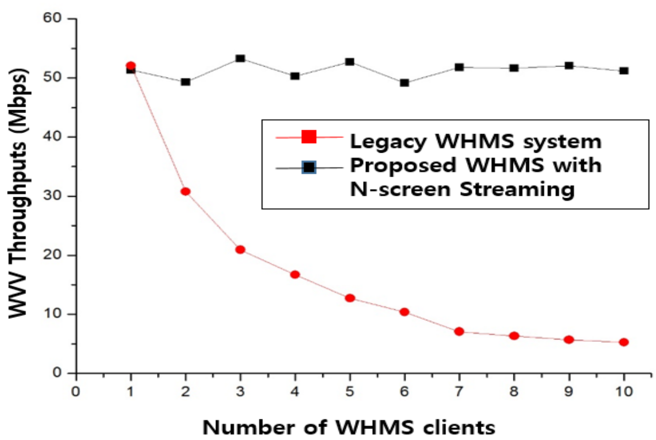

Figure 8. WVV Throughput According to the Number of WHMS Clients

Figure 9 shows WVV delays according to the number of WHMS clients. In Figure 9, the delay of WHMS device using the proposed multimedia streaming scheme does not change regardless of the number of WHMS clients. This is because WHMS host can multicast larger multimedia WVV data to the adjacent WHMS devices using the proposed service interval-based MAS allocation and N-screen DRP Availability IE.

However, as the number of WHMS clients increases, the WVV delay of WHMS devices using the legacy WHMS system gradually increases since the legacy WHMS protocol only supports the communications without the service interval-based MAS allocation between the WHMS host and the WHMS devices. As shown in Figure 8, the number of WVV transmissions from WHMS host to WHMS devices increases according to the number of WHMS clients since the legacy protocol does not support N-screen DRP Availability IE scheme. Thus, the WVV delay of WHMS device using the legacy WHMS is proportional to number of WHMS clients.

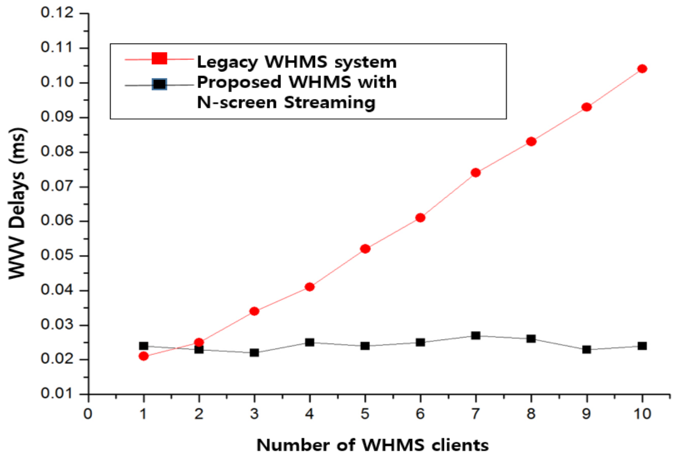

Figure 9. WVV Delay According to the Number of WHMS Clients

5. Conclusions

In this paper, we propose a multimedia streaming scheme by using the proposed N-screen resource allocation and N-screen DRP Availability Information Element, for n-screen service in wearable health-monitoring systems (WHMS) networks. The proposed scheme can improve throughput performance of WHMS Vital Video (WVV) applications. Also, proposed scheme can reduce WVV delay since it minimizes the multicast WVV data delivery process. Compared with the legacy WHMS system, the proposed streaming scheme is very simple and efficient as it does not require additional hardware. These merits make the proposed WHMS system extremely inexpensive to implement in hospital WHMS network and bio cloud-computing applications.

Author Contributions

Kyeong Hur wrote the manuscript. Won-Sung Sohn designed experiments. Kil Young Kwon provided technical supports.

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Communication 2015 & Mobile and Wireless 2015 held on April 15-18, 2015, Jeju Island, Korea."

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