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Context-Aware Handover with Power Efficiency for u-Healthcare Service in WLAN

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Abstract—**The IEEE has recently started to develop a standard for the wireless body area network (WBAN). Providing high mobility with guaranteed QoS over the u-healthcare network which are built from the converged WBAN and WLAN systems is a challenging task. This article proposes a context-aware mobility management framework which can support high mobility in the converged WBAN and WLAN networks. The salient feature of the approach is that in order to support seamless mobility management, the context information on the communication environment, the type of service, and the medical emergency has been utilized, while minimizing the power consumption. The service model and algorithms for the context-aware mobility management have been developed in detail. Simulations have finally been performed to show the efficiency of the proposed mechanism.**

Keywords-*Context-Aware Handover*; ***WLAN; WBAN; u-Healthcare; power efficient; QoS***

I. INTRODUCTION *(HEADING 1)*

Recently, there have been increasing interests in the ubiquitous healthcare system (u-healthcare system). The ubiquitous computing technologies that have been developed since the conceptual inception of Mark Weis have recently been applied to healthcare services to improve the efficiency and quality of the system [1][2]. Characteristics of modern medical work show the extreme mobility, ad-hoc collaboration, interruptions, and the high degree of communications, which are fundamentally different from those of typical office work [3]. In the u-healthcare system, the vital body signs such as electrocardiograph (ECG), oxygen saturation (SpO2), heart rate (HR) and blood pressure (BP) can be continuously monitored in an autonomous way, while the patients and/or medical doctors are in movement. This can make preventive and on-time treatment of chronic diseases for the aged to be supported without disturbing their daily lives.

The IEEE recently starts to develop a standard for wireless body area network (WBAN) [4] for communication on, in or around the human body to serve a variety of medical as well as other applications. The u-healthcare information infrastructure may consist of converged WBAN [4] and wireless local area network (WLAN) [5]. The support of session continuity during movement on this converged network is important because it may lose vital information during the movement of patients and/or doctors. Furthermore, the QoS (Quality of Service) of the communication session should also be maintained a peak performance, while minimizing power consumption. The key to the successful building of the u-healthcare system is to make these diverse communication technologies to be interoperable and converged in such a way that the high degree of mobility and communications be supported securely, reliably, cost-effectively, and in an power-efficient way.

The objective of this paper is to develop a context-aware handover technique for u-healthcare services, while preserving the optimality in power, i.e., power consumption. In particular, we focus on the integrated WBAN and WLAN systems in which the medical communication session can be maintained in a power-efficient way, while the patients and/or doctors are in movement. The salient feature of the approach which has been suggested is that in order to support seamless mobility management, the contextual information on the communication environment, the type of service, and emergency has been utilized, while minimizing the power consumption.

There have been a considerable amount of research works done for supporting the mobility management over similar and/or heterogeneous wireless networks. These include fast layer 2 handover mechanisms [6] and various IP mobility management standards [7]. However, these methods may not be directly applicable to handover technique for the u-healthcare networks. However, most of these previous research works did not take into account the power-efficiency issue for mobility management. We propose a new technique at WLAN to provide continuous Internet communication session during movement, while minimizing power consumption.

In the subsequent sections, context-aware layer 2 handover mechanism in wireless LAN, which can provide fast handover with guaranteed QoS for real-time u-healthcare multimedia services are presented. To this end, the scanning period and the number of channels per scanning for handover of the WLAN systems are dynamically adapted to the type of u-healthcare applications and wireless networking environments, so that both the degradation of application service quality and signaling overhead are minimized simultaneously. Within our knowledge, almost no published work exists on dynamically adapting the layer 2 handover procedure, with minimal power consumption, to the application type for guaranteeing the quality of service (QoS) of the diverse real-time multimedia applications.

In Section II, we present the context-aware WMAN and WLAN convergence architecture and the service model for context-aware handover with power efficiency. In Section III, the algorithm for context-aware handover is described, and

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the performance evaluation in Section IV. The conclusion finally follows in Section V.

II. WBAN AND WLAN CONVERGENCE ARCHITECTURE AND SERVICE MODEL FOR U-HEALTHCARE SERVICE

A. WBAN and WLAN Convergence Architecture for u-Healthcare Service

The IEEE has recently started to develop a standard for the wireless body area network (WBAN) [4]. The IEEE 802.15 Task Group 6 (BAN) [4] is developing a communication standard optimized for low power devices and operation on, in or around the human body (but not limited to humans) to serve a variety of applications including medical, consumer electronics / personal entertainment and so on. The characteristic of WBAN is that it can not only provide the transport service of the medical physiological information such as ECG, EEG and SpO2, but also provide the services for high-bandwidth multimedia services. Table I shows the draft proposal of QoS requirements of the various applications over the wireless body area network (WBAN) [4]. As described before, since the WBAN may serve a variety of applications including medical, consumer electronics / personal entertainment and others, there are a variety of target data rates and the latency requirement for voice application is drastically different from others.

TABLE I. QOS REQUIREMENT OF VARIOUS APPLICATIONS AT WBAN

Application	Target data rate	Latency	BER
Drug Delivery	< 16 Kbps	< 250 ms	$< 10^{-10}$
Deep Brain Stimulation	< 320 Kbps	< 250 ms	$< 10^{-10}$
Capsule Endoscope	1 Mbps	-	$< 10^{-10}$
ECG	192 Kbps	< 250 ms	$< 10^{-10}$
EEG	86.4 Kbps	< 250 ms	$< 10^{-10}$
EMG	1.536 Kbps	< 250 ms	$< 10^{-10}$
Glucose level monitor	< 1 Kbps	< 250 ms	$< 10^{-10}$
Audio	< 1Mbps	< 250 ms	$< 10^{-5}$
Video / Medical imaging	< 10 Mbps (e.g., Standard Video)	< 250 ms	$< 10^{-3}$
Voice	100-50 Kbps per flow	< 10 ms	$< 10^{-3}$

Fig. 1 shows the configuration of the u-healthcare convergence network which is built by integrating WBAN and WLAN. The WBAN is used for continuous monitoring of various vital signs such as EEG, ECG, BP, etc. It can also be used for transmitting multimedia data from MP3 devices and video cameras. In the cost-effective u-healthcare network systems, vital signs which are collected from non-invasive physiological sensors are first transported wirelessly through WBAN, and then through WLAN, and finally through the Internet to the medical information servers and/or doctors, using fixed-mobile convergence technology. In addition to the vital signals, the contextual information such as weather, temperature and emergency case may be transported for context-aware patient-specific real-time treatments.

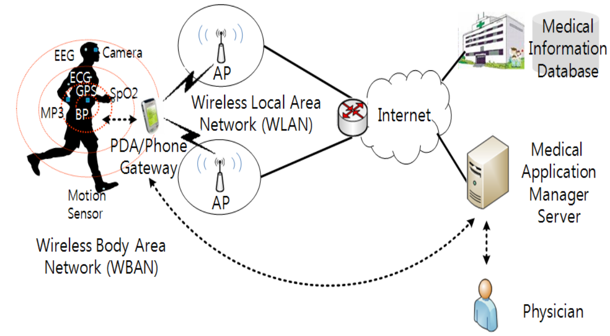

Figure 1. Configuration of WBAN and WLAN convergence network for u-healthcare service

The PDA/Phone Gateway (Body Gateway) in Fig. 1 performs the convergence function for the integration of WBAN and WLAN. Both patients' data and contextual information are integrated at the gateway, and transported to the medical centers or hospitals using IP protocol over the Internet. This convergence gateway can be realized by a smart phone or other mobile devices such as a tiny PC and PMP. The main convergence function of the mobile gateway includes the support of interoperability of WBAN and WLAN, and the seamless mobility management between WLANs.

B. Service Model for Context-Aware Handover with Power Efficiency

In this section, the service model for application-aware handover is presented. Fig. 2 depicts the buffering structures at the mobile gateway (hereafter it is called a mobile node) for the u-healthcare multimedia streaming application. The mobile node starts to play out the streaming data after some amount of data is pre-fetched in the buffer. After playing out the service, the data continuously gets into the buffer from the network, with the rate of F(t), so the service can be provided without disruption. Here, F(t) is called the Fill Rate, and it indicates the amount of data which arrives at the application buffer during the unit time. In Fig. 2, D is the amount of data which leaves the buffer during the time unit. F(t) is termed as the input rate, and D is called the output rate. It is noted that F(t) varies along with time, dependent of network conditions, delay and bandwidth, but D is fixed and independent of time.

Definition 1: The interrupt allowance time (AIAT) of an application service is defined as the time during which the streaming application can be played out without service degradation although the layer connection is disrupted due to scanning operation of the handover procedure.

Let us define the amount of pre-fetched data at time t as Q(t). Q(t) depends on the input rate F(t). For a real-time streaming service, Q(t) can be obtained by estimating the moving average of F(t). D is usually constant, and depends on the type of codecs. For the MPEG 1 codec, D is 1.5 Mbps, and for MPEG 3, it is between 3 Mbps and 6 Mbps [8]. In general, the application interrupt allowance time depends on the buffer size, multimedia codec, and error concealment

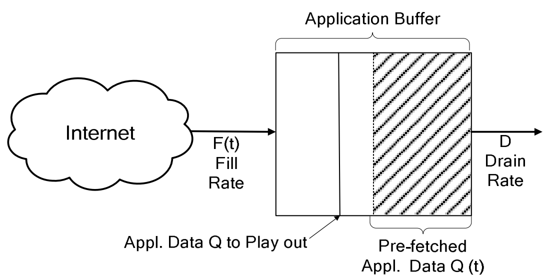

Figure 2. Application buffer structure for real-time u-healthcare service

methods, and the processing capability of the mobile node. For the stored video/audio service using the RTSP streaming protocol, the value of T is between 2 sec and 5 sec.

The maximum application interrupt times for various types of real-time multimedia applications are usually as follows: for stored video or audio applications, it may take 2 to 5 seconds of application interrupt allowance time, which are usually RTSP streaming protocol. For VoIP using the G. 711 codec, the application interrupt allowance time may take around 20 to 50 milliseconds. For real-time video conferencing service, it is assumed to take around 50 milliseconds.

As shown in Fig. 2, the multimedia application using streaming protocol is played out after the data has filled up the application buffer and reaches some threshold value at Q. Therefore, even though the connections at layer 2 is disrupted, the application can be continuously played out without service disruption until the pre-fetched data, i.e., Q bytes of data, in the application buffer is drained out. Therefore, the maximum of application interrupt allowance time for a multimedia application using streaming protocol is Q/D sec. This is denoted as T.

Below is a theoretical framework for the context-aware seamless layer 2 handover with minimal consumption in wireless LAN.

Lemma 1: In wireless LAN, the maximum value of AIAT of an application at a mobile node is T.

Proof: For a given time t, there exists Q(t) data at the application buffer. Since the streaming application can be at most played out without service degradation during Q(t)/D, T is the maximum value of AIAT. □

Generally, the active scanning operation to get the neighbor AP information during movement incurs both packet loss and power consumption. This is because the current connection is temporarily disrupted during the scanning operation, and the probing process in the active scanning requires power consumption which can otherwise be used for data packet transmission. Generally, the mobile node has limited power, so that the power consumption for the scanning operation should be minimized.

Lemma 2: In wireless LAN, the power consumption for the handover procedure is proportional to the number of scan operations,

Proof: As the number of scan operation decreases or increases, the number of probing processes to searching the wireless LAN channel also decreases or increases, respectively. This in turn decreases or increases respectively the power consumption for the handover operation. □

Theorem 1: As a mobile node moves in a wireless LAN, the handover procedure with minimal power consumption while sustaining the service quality of an application is to perform one scan operation during T sec.

Proof: By Lemma 1, an application at a mobile node can at most play out the service without service degradation during T sec, regardless of the number of scan operations of the layer 2 handover procedure. According to Lemma 2, since the power consumption for the handover procedure is proportional to the number of scan operations, performing one scan operation during T sec, results in minimal power consumption for the handover procedure while sustaining the service quality of the application. □

Corollary 1: As a mobile node moves in a wireless LAN, the handover procedure for getting the best neighboring AP information with minimal power consumption while sustaining the service quality of an application is performing one scan operation during T sec.

Proof: According to Theorem 1, the handover procedure with minimal power consumption while sustaining the service quality of an application is performing one scan operation during T sec. As a mobile node moves in a wireless LAN, the mobile node may get better information by performing more frequently the scan operation. However, these frequent scan operations increases the power consumption. Therefore, the scan operation for getting the best AP information with minimal power consumption is performing one scan operation during T sec. □

III. ALGORITHM FOR CONTEXT-AWARE HANDOVER IN WLAN

Fig. 3 shows the context-aware handover algorithm which can find the optimal next access point (AP) with minimal power consumption, while preserving the service quality during handover, taking into consideration the networking conditions. The algorithm in Fig. 3 consists of three parts; identifying the type of application and getting the neighboring AP information, i.e, the identifying the context, the handover preparation, and channel switching for AP handover. In the identification of the type of context, the main application which is currently running on the mobile node is identified, and the values of application interrupt allowance time and scan granularity are determined. In particular, the end-to-end delay time and allowable packet loss are taken into account for determining the proper value of the scan granularity in order to preserve the service quality of the application during handover.

In Theorems 1 in Section III, it was found that the scanning method to achieve the minimality in both power consumption while preserving the service quality of the application was to scan one wireless LAN channel during the maximum application interrupt time T sec. The context-aware handover algorithm in Fig. 3 takes advantage of these properties of the scan operation, so that it tries to perform one scan operation, every T sec, as long as the application

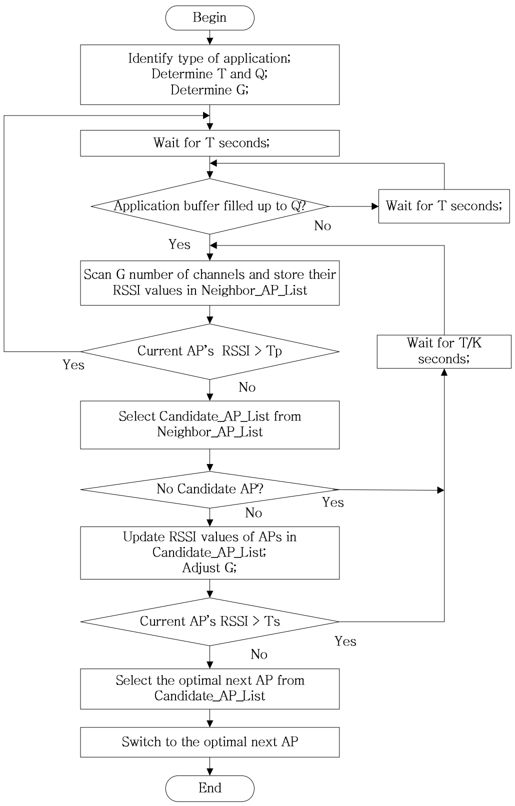

Figure 3. Application-aware handover algorithm with guaranteed QoS and **minimal power consumption**

buffer contains enough pre-fetched data to preserve the service quality. However, the input data rate at the application buffer depends on network conditions. It usually varies with time t, so that the amount of data which has been filled up at the application buffer during T sec may be less than Q. In this case, the algorithm prolongs the scan operation to the multiple of T sec until the application buffer fills up to Q. Therefore, the scanning period varies in accordance with the network conditions, with the value of N*T seconds where N is an integer and usually less than 5. N is also decided by the application type.

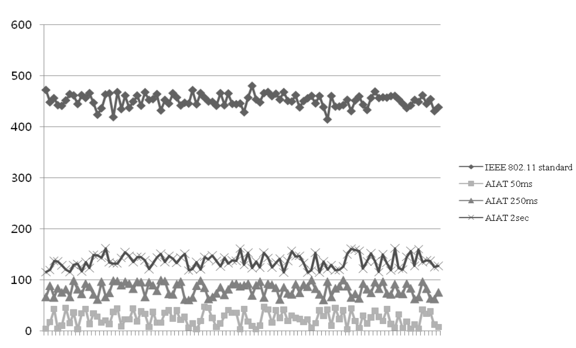

Figure. 4. Handover latency of IEEE 802.11 standard and context-aware handover

IV. PERFORMANCE EVALUATION

In this section, we have evaluated the performance of context-aware handover by simulation. In particular, we have compared the performance of the context-aware fast handover with that of existing layer 2 handover method based on the IEEE 802.11 standard. Since the existing simulator such as NS2 does not provide mechanism for measuring the power consumption, we have written a simulator with C++ language, which runs under Window XP operating system. Additional benefit resulting from writing a simulator is that we can simulate the performance of the cross-layer optimization mechanism to model the application type, and the pre-scanning and partial scanning methods at layer 2. The simulator gets the scan granularity, scan cycle (T-T/N), application service Q (t) and Q value, and power consumption as input values of the application-aware handover algorithm in Fig. 3., and investigates the tradeoff between scanning delay and power consumption for guaranteed QoS of various type of medical application service.

For simulation, we have placed the four APs in the 500m×500m area. APs are placed on the following coordinates: (50, 50), (50, 350), (350, 50), and (250, 350). It is assumed that the mobile node moves in the diagonal direction from (0, 0) to (500, 500). In order to model the power consumption for scanning operation, it is assumed that WLAN NIC consumes average of 450mW when it is in state of "Radio on" or just connected the network with no data transmission. But it consumes about 1600mW for scanning the neighboring AP [9]. The data transmission rate is assumed to be a maximum of 54 mbps of the IEEE 802.11g standard. The values of minimum channel waiting time and maximum channel waiting

time for the active scan operation are set to 20 ms and 40 ms as in [10]. The channel switching time is assumed to be 5 ms [11]. The model of calculating the radio signal strength as the mobile node is in movement is obtained by using the formula in [12], which is determined by the distance between a mobile node and an AP.

Fig. 4 shows the handover latency for various medical application services. Both the standardized handover mechanism of the IEEE and the application-aware handover mechanism have also been compared.. The upper-most graph with diamond notation indicates the behaviour of the IEEE standard, while the others are the results of the context-aware handover algorithm. As shown in the figure, the handover delay of the IEEE standard is relatively constant irrespective of the type of applications. However, as shown in Fig. 4, IEEE standard handover has the latency which is greater than 400 ms, so it might cause service disruption for the application with fewer AIAT value than 400 ms.

On the contrary, the handover latency of those obtained by the proposed context-aware mechanism exhibits the varying performance in accordance with the type of the application. For example, the stored video service with the value of a few seconds of AIAT generally has the larger value of handover latency than those of EEG and ECG. The context-aware handover demonstrates better performance in handover latency than the IEEE standard mechanism.

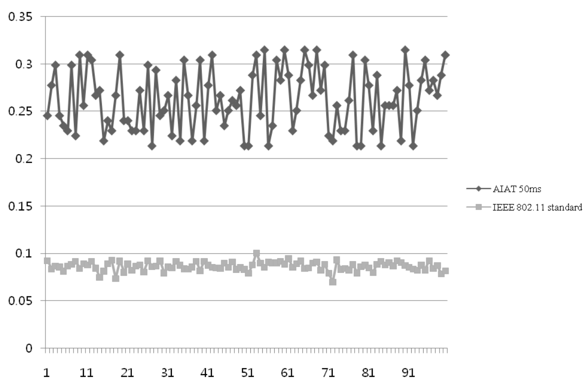

Figure 5. Power consumption of IEEE 802.11 standard and AIAT 50ms

In Fig. 5, the upper-most graph shows the power consumption generated by the full scan operation, employing the IEEE standard handover mechanism. It shows that the power consumption for the full scan operation is in the range of about 0.07 mW and 0.1mW. Power consumption has some relation with the elapsed time for the scan operation, which is determined by minimum channel waiting time, the maximum channel waiting time, and the total number of channels, and the channel switching time.

The lower graph in Fig. 5 shows the power consumption for various applications which have the AIAT value of 50 ms, in which the application-aware handover algorithm is applied. As described before, the application-aware handover algorithm takes advantage of both pre-scan and partial scan mechanisms in order to guarantee the QoS of an application. For the application with small AIAT, the partial scan is more frequently executed to prevent the degradation of the QoS of an application service. This may incur more frequent switching between scan mode and data transmission mode at WLAN interface card, so that the power consumption increases due to this frequent switching operation. For the value of 50 ms AIAT, the range of consumed power is between 0.23mW and 0.33mW, as shown in Fig. 5. In comparison with that of IEEE standard scanning method for the full scan operation, the power consumption is almost three-fold. However, it gives an advantage that the quality of the application service is not degraded.

V. CONCLUSION

The provisioning of u-healthcare service requires reliability, security and cost-effectiveness because it is related to human life, and it should be available to rich people as well as poor elderly people. Most of the previous work done on WLAN handover management did not take into account these situations. In this article, a context-aware handover architecture u-healthcare service in wireless local area network, which takes into account the power efficiency has been presented.

The service model of the power-efficient handover is presented, and algorithm for the realization of context-aware mobility management is presented. Finally, the performance of the proposed model and algorithms has been evaluated by simulation. The simulation results show that the proposed system can be effectively used in various types of u-healthcare application services. Future research work may include the design of a more-detailed policy for the representation of context and rules.

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