Wireless Context-Aware Healthcare System Based on Sensor Web 2.0

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***Abstract*—As the context-aware technologies and RFID-based sensor devices continue to emerge, the existing healthcare systems are the lack of a uniformly access to cope with the heterogeneous effects, including various context-aware healthcare information presentation, client device constraints, and context-aware healthcare middleware. To allow interoperability among the various context-aware healthcare systems, a common standard is needed to uniformly access context-aware healthcare information provided via a fundamental infrastructure. The Sensor Web 2.0 technologies provide a catalytic solution to this problem. This study addresses these issues developing a RFID-based Context-aware Healthcare System (RCHS) which is based on wireless communication architecture and is implemented in the Web 2.0 environment. The RCHS is composed of RFID-based Healthcare Sensor, RFID-based Context-aware Healthcare Middleware, and Mobile Client to allow a continuous and context-aware health monitoring for patients.**

***Index Terms*—Wireless sensor network, healthcare system, sensor web 2.0, rfid, context-aware.**

I. Introduction

Context awareness was first discussed by Schilit and Theimer [1] to develop context-aware systems that allow users to access information and services according to their current context, including location, time, identity, activity, and preferences. Radio Frequency Identification (RFID) [2] provides automatic identification and sensing capabilities have been integrated to the context-aware applications. RFID is being gradually adopted and deployed in a wide area of context-aware applications, including healthcare, business processes, security, and smart home. The above RFID-based context-aware applications are developed based on Internet to provide real-time information services. These days, the Internet has greatly changed our way of sharing resources and information. Web 2.0 [3] has become the mainstream technology for information systems based on Internet.

Traditional healthcare information systems can benefit from the use of context-aware and RFID-based sensor technologies. This paper adopts Sensor Web 2.0 technologies to fulfill context-aware healthcare system based on RFID-based sensors. Automatic monitoring is an import part of any healthcare systems, such as hospital, elderly nursing home, in-home elder healthcare, and healthcare medication management. This study develops a RFID-based Context-aware Healthcare System (RCHS) which is based on RFID-based sensors and is implemented in the new generation Web 2.0 environments. Furthermore, the proposed RCHS provides healthcare information on two different schemes, including push-based scheme and pull-based scheme. The pull-based scheme allows users to pull the context-aware healthcare information they are interested in. The push-based scheme allows Context-aware Healthcare Middleware to push the important context-aware healthcare information to patient's family in real-time.

This paper is organized as follows. The next section briefly reviews some existing healthcare applications. Section III discusses how Sensor Web 2.0 technologies can be used in context-aware healthcare systems. In Section IV, we implemented the RCHS to demonstrate the mobile ubiquitous computing application. Finally, summary and concluding remarks are included.

Manuscript received April 9, 2012; revised December 12, 2012.

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II. Related Work

Traditional healthcare information systems can benefit from the use of context-aware and RFID-based sensor technologies [4]-[9]. In [6], authors present a distributed context-aware access control mechanism for pervasive process-based healthcare systems built on a Grid infrastructure. An advanced healthcare application [9] is developed based on an ad hoc interaction of mobile body sensor networks to allow a continuous and context-aware health monitoring for patients. Wireless sensor technologies have been integrated into a home healthcare system [7], which supports various wearable sensors to provide extended monitoring for elderly patients. The main problem of the mentioned above healthcare systems is that it is the lack of a uniformly access to cope with the heterogeneous effects, including various context-aware healthcare information presentation, client device constraints, and context-aware healthcare middleware. This paper argues that Web 2.0 technologies provide a catalytic solution to this problem.

The Web 2.0 [10] technologies provide a medium for the sharing and exchange of resources. These resources, such as Web feed and Web API, allow web developers to take advantage of these resources to enrich their own applications or produce new integrated solutions by integrating resources. Many Internet companies have enabled easy access to the web resources that they provide. Anyone can create a new integrated mobile ubiquitous application with these resources. When an application combines resources from different websites to produce a new web application it is called a Web 2.0 Mashup [3]. Social Web 2.0 technologies enables the

DOI: 10.7763/IJIMT.2013.V4.432

development of mobile ubiquitous module easy to integrate the various Web standards to facilitate the sharing and exchange of ubiquitous resources including ubiquitous information and ubiquitous services. It facilitates the massive ubiquitous resources to store up by the XML-based pattern in the Ubiquitous Web [11].

III. Context-Aware Healthcare System Based on Sensor Web 2.0 Technologies

The Web 2.0 Mashup is an emerging Web development paradigm that combines functionality from different websites and enables the loose coupling of heterogeneous Web resources. This study adopts Sensor Web 2.0 technologies, including Web feed, Web services and Web presentation for supporting most of the tasks involved in dealing with context-aware healthcare systems development. Sensor Web 2.0 can be regarded as a kind of Web 2.0 Mashup, which integrates Web 2.0 and wireless sensor technologies as a basis for supporting the Internet applications. It enables the development of Web-based applications easy to integrate the various Web 2.0 standards to facilitate the sharing and exchange of information in the Internet. This study argues that Sensor Web 2.0 can be adopted as a common scheme to uniformly integrate Web applications via a fundamental service model.

A. Context-Aware Healthcare Information

Context-aware healthcare information can be acquired from heterogeneous and distributed sources, including sensors, profile files, and applications. A Web feed contains a structured information source which is written in XML to facilitate the machine-readable. This means that Web feeds can be used to automatically transfer context-aware healthcare information from one context-aware healthcare system to another, without any human intervention. One major feature of Web 2.0 is to adopt Web feeds to build a more maintainable and cooperative Web. Web feeds allow both context-aware healthcare systems to publish frequently updated context-aware healthcare information such as Weblog, location, time, identity, activity, and preferences. RSS [12] and Atom [13] are currently the two main formats of Web feed. RSS is a family of Web feed formats specified in XML standard. There are three different version of RSS, namely Rich Site Summary, RDF Site Summary and Really Simple Syndication. The Really Simple Syndication (RSS 2.0) is the most widely used. Unlike RSS, Atom is proposed RFC 4287 and is defined with XML schema. The detail comparisons of RSS and Atom are shown in Table 1.

Besides XML-based Web Feeds, JSON (JavaScript Object Notation) is another option for data exchange in the Internet. JSON a lightweight computer data interchange format that a text-based and human-readable format for representing simple data structures. Its main application is in Ajax web application programming, where it serves as an alternative to the traditional XML-based data format. The XML-based data format is more complex than JSON, which is specifically designed as a data interchange format.

TABLE I: The Comparison of RSS and Atom

	RSS	Atom
version	RDF Site Summary (RSS 0.9 and 1.0) Rich Site Summary (RSS 0.91, RSS 1.0) Really Simple Syndication (RSS 2.0)	Atom 1.0
publisher	Harvard University	IETF community RFC 4287
namespaces	no namespaces	http://www.w3.org/2005/Atom
schema	no XML schema	XML schema provide
XML standard	Yes, support Well-formed XML document	Yes, support Validating XML document
mime type	no mime type	application:atom+xml

Using Web feeds to present the context-aware healthcare information have a few advantages. (1) Users can be notified of new context-aware healthcare information without needing to visit the context-aware healthcare systems. (2) Web feeds provide summaries of context-aware healthcare information together with hyperlinks to the full versions of the Web-based healthcare content. (3) Web feeds allow users to pull the context-aware healthcare information they are interested in rather than data being pushed to the users.

B. Web Services

Web services are used to support a reusable solution for context-aware healthcare information acquisition and transformation to simplify the development of context-aware healthcare systems. Web 2.0 Mashups use Web services technologies to facilitate context-aware healthcare information exchange between healthcare systems and allow the creation of new context-aware healthcare applications. Most of Web services hide the detailed protocols from the context-aware developers and make it easier for the developers to use. The main types of Web services are: XMLHttpRequest, XML-RPC, SOAP, and REST.

XMLHttpRequest is not a web service technology but a Web API that provides scripting languages to transfer XML or other text data between a client and a server. It is used to communicate asynchronously with a server-side component. XML-RPC [14] is a remote procedure calling employing HTTP as the transportation protocol. It provides a standard for heterogeneous programs to communicate with each other regardless of their implementation language and system platform. Simple Object Access Protocol (SOAP) [15] is another communication protocol for Web services that emerged immediately after the XML-RPC. It is developed to address some of the limitations of XML-RPC, including only for RPC over HTTP, not easily extendable, and no support WSDL. Representational State Transfer (REST) [16] is a style of software architecture used to describe how Web resources, such as web service, web page, text, database, or website, are defined and addressed. The main advantages of REST-based Web services are lightweight, human readable, and easy to build.

C. Context-Aware Healthcare Information Presentation

Web presentation technologies are mainly to provide a valid markup language for context-aware healthcare

information presentation on a specific device. The same context-aware healthcare information needs to be rendered differently on different devices. By considering the physical and performance constraints on a device, such as screen size, memory size, and connection bandwidth, a significant challenge in context-aware healthcare information rendering is automatically converting heterogeneous markup based documents into the desired XML-based format, which can be understood by a specific device. The heterogeneous markup-based context-aware healthcare information conversion is a type of transcoding [17], which is a technology used to adapt the visual output of healthcare information so that they can be viewed or processed by the multiple devices of healthcare systems.

HTML is widely regarded as the standard publishing language of the Web environment. XHTML (eXtensible Hyper Text Markup Language) a reformulation of HTML 4.0 based on XML standard. It is intended to be used as a language for content that is both XML-conforming and operates in HTML 4.0 conforming user agents. Based on XML, XHTML is relatively easy to extend new elements or additional element attributes for general user agents. AJAX (Asynchronous JavaScript and XML) is not a new technology or language, but a new framework that combines various existing technologies, including XML, XHTML, XMLHttpRequest [18], and JavaScript. With the promotion of the XML and JavaScript, the AJAX framework becomes a basic ingredient in Web 2.0 applications. It supports a more interactive presentation of context-aware application has enhanced online collaboration and sharing context-aware healthcare information among healthcare systems.

IV. RFID-Based Context-Aware Healthcare System

The main components of our proposed RFID-based Context-aware Healthcare System (RCHS) include: the RFID-based Healthcare Sensor, Context-aware Healthcare Middleware, and Client. The devices relevant to RCHS are described in Table II. In the RCHS, patient health information are collected through the SYRD245-1N (RFID Reader), transferred and stored into the ASUS TS300E5. The dataflow-oriented architecture of RCHS is depicted in Figure 1. The Web 2.0 technologies are used in RCHS summary in Table III.

RFID-based Healthcare Sensor is composed of SYRD245-1N (RFID Reader) and various active RFID healthcare tags, including SYTAG245-HT1, SYTAG245-TM, and SYTAG245-2K. Each RFID healthcare tag has a unique ID ties to an entity for identification. The SYRD245-1N servers as a RFID healthcare tag reader as well as the context-aware healthcare information transceiver. The SYRD245-1N is connected to the Context-aware Healthcare Middleware and the events are sent in real time.

Context-aware Healthcare Middleware is a Web server that provides the function of dynamic healthcare information transcoding and data repository. It uses XML-based documents and web services technologies to facilitate context-aware healthcare information reusability. This middleware comprises Monitor Agent, Transcoding Agent, SMS Agent and Healthcare information Repository. The Monitor Agent receives and filters the healthcare information from the SYRD245-1N. The Transcoding Agent listens to the client's request with patient ID to acquire the healthcare information form healthcare information repository, and then converts the healthcare information into a XML-based document to response to client. The SMS Agent is developed as a Web service to sent a SMS message to patient's family.

Client Device interacts with the Context-aware Healthcare Middleware through internet connections to retrieve the healthcare information. Various client devices, including desktop PC, personal digital assistants (PDA), smart phone, and notebook, are increasingly becoming connected to the Internet. The same healthcare information needs to be rendered differently on different client devices.

TABLE II: Devices in the RCHS

Device	Description
SYRD245-1N (RFID Reader)	The SYRD245-1N is an active RFID reader that is connected to an Ethernet network and the events are sent in real time.
SYTAG245-HT1 (RFID Tag)	The SYTAG245-HT1 is an active RFID temperature and humidity sensor tag. Each SYTAG245-HT1 has a unique ID ties to a room for identification.
SYTAG245-TM (RFID Tag)	The SYTAG245-TM is an active RFID wristband tag that supports to detect the body and ambient temperature. Each SYTAG245-TM has a unique ID ties to a patient for identification.
SYTAG245-2K (RFID Tag)	The SYTAG245-2K is an active RFID tag with SOS button. Each SYTAG245-2K has a unique ID ties to a patient for identification.
WaveCom Q2303A (GSM Modem)	It serves as a GSM cell phone to transmit SMS messages over a GSM network just like an ordinary cell phone. GSM modem requires a SIM card to work and can be connected to computer to be used as modem for the SMS sending/receiving.
ASUS TS300E5 (Context-aware Healthcare Middleware)	It is a PC server that serves as a Context-aware Healthcare Middleware to provide the function of dynamic healthcare information generation and transcoding.
HP iPAQ 212 (Mobile Client)	It is a PDA that displays patient healthcare information using RSS reader.

TABLE III: The Related Sensor Web 2.0 Technologies Employed in RCHS

Web 2.0 technology	Service Type	Description
RSS	Web feed	The healthcare information is described in RSS format to support to mobile phone RSS reader.
AJAX	Web interaction	A sample client was built using Java Server Page (JSP) and AJAX to query the ASUS TS300E5, and display the patient healthcare information in real-time.
SMS Web service	Web Service	The SMS Agent is developed as a Web service to sent a healthcare SMS message to patient's family.
XHTML	Web presentation	The healthcare information is rendered in XHTML for desktop PC.
Google charts	Web presentation	The context-aware healthcare information, such as temperature and humidity, can be displayed in charts or graphs by the Google charts API.

The following steps explain the message flow illustrated in Fig. 1:

1) Each patient has an SYTA245-TM tag and SYTAG245-2K tag associated with a unique ID as the

patient identification. Each ward has a SYTA245-HT1 tag associated with a unique ID as the ward identification. These active RFID healthcare tags send health or environment context-aware information to the SYRD245-1N.

2) SYRD245-1N receives the context-aware healthcare information and then sends them to ASUS TS300E5 by local Ethernet. The ASUS P320 parses the employee attendance information to filter the available information.

3) The ASUS TS300E5 invokes Monitor Agent to filter the available healthcare information, and then save into the healthcare information repository.
   - It invokes Monitor Agent to filter the available healthcare information.
   - It encodes the healthcare information to an XML-based document.
   - It sends the XML-based document to ASUS TS300E.

4) The step is a pull-based interaction scheme that accomplishes the following tasks:
   - The various devices, such as mobile PDA or desk PC, can send a request to ASUS TS300E5 with the patient ID to browse the patient healthcare information.
   - The ASUS TS300E5 invokes Transcoding Agent with patient ID to acquire the healthcare information form healthcare information repository, and then converts the healthcare information into a XML-based healthcare document.
   - The XML-based healthcare document can be converted to various XML-based documents, such as RSS (shown as Fig. 2) or XHTML document, to display in mobile PDA and desktop PC, respectively.

5) The step is a push-based interaction scheme that accomplishes the following tasks:
   - ASUS TS300E5 requests SMS Agent with the real-time healthcare information to start WaveCom Q2303A (GSM Modem).
   - WaveCom Q2303A serves as a GSM cell phone to transmit SMS message that contains the real-time healthcare information. The SMS message is sent to SMSC (SMS Center).
   - SMSC is responsible for handling the SMS operations and routes the SMS message to mobile phone.

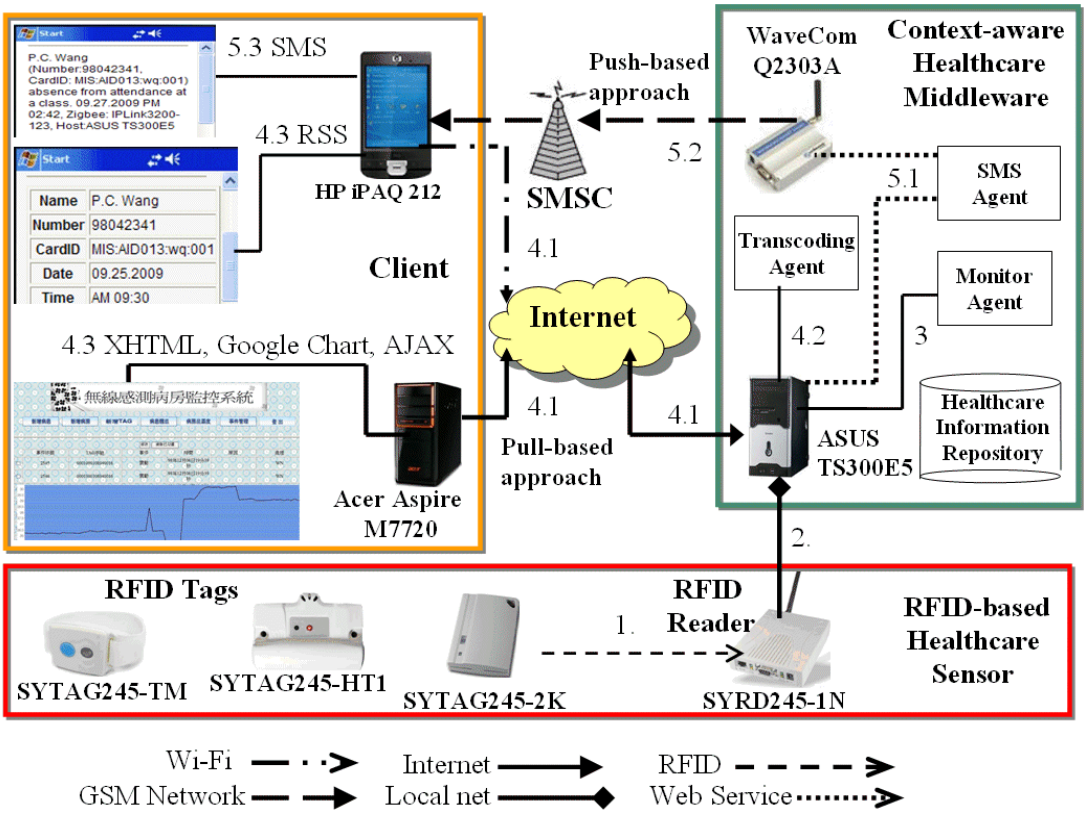

Fig. 1. The flow-oriented RCHS architecture.

```
<?xml version="1.0" encoding="utf-8" ?>
<rss version="2.0" >
<channel>
 <title>RFID-based Context-aware Healthcare System</title>
 <link>http://140.130.35.139/?source=rss</link>
 <description>The healthcare information of  …</description>
 <category> body temperature </category>
 <generator> SYTAG245-TM (1902-2231-3201)</generator>
 <ttl>30</ttl>
<item>
  <title>Patient: Peter Lee, the first roll call </title>
  <link>http://140.130.35.139/2009HTC/20121015.jsp</link>
  <pubDate> Fri, 06 April 2012 10:17:27 GMT </pubDate>
  <guid>HTC:POI391:PQ:021</guid>
  <subject>Healthcare information</subject>
  <description>
  <![CDATA[The first roll call -
        <br> temperature: <b>32</b>
        <br>time: <b> Fri, 06 April 2012 10:15:21 GMT </b>
        <br>RFID Reader ID : <b> SYRD245-1N </b>
        <br>Context-aware Middleware: <b> ASUS TS300E5</b>
  ]]></description>
```

</item>…..
</rss>

Fig. 2. Partial code of RSS healthcare information.

V. Conclusion and Future Work

This study developed a RFID-based Context-aware Healthcare System (RCHS) based on the wireless communication architecture to demonstrate how Web 2.0 technologies could enhance added value of classic healthcare system. The RCHS is composed of RFID-based Healthcare Sensor, Context-aware Healthcare Middleware, and various Clients. The main advantage of our RCHS is that it is developed based on Web 2.0 technologies to facilitate the reusability of healthcare information.

Context-awareness is a very important feature for RFID-based sensor networks to enhance existing healthcare systems by finding right context-aware healthcare information and right context-aware healthcare services in the right place at the right time. One future work is to investigate how to integrate Semantic Web [19]-[22] technologies into context-aware healthcare systems to facilitate the implementation of intelligent healthcare applications.

Cloud computing [23], [24] has become a popular information technology solution in recent years. The term refers to the important and long-term trend in computing over the Internet. Another topic for future work is extending the accessibility of RCHS to the cloud computing environment for global optimization and composition of cloud computing services.

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