Intelligent Multi-Agent Middleware for Ubiquitous Home Networking Environments

Minwoo Son, Seung-Hun Lee, Dongkyoo Shin, and Dongil Shin

Abstract—The next stage of the home networking environment is supposed to be ubiquitous, where each piece of material is equipped with an RFID (Radio Frequency Identification) tag. To fully support the ubiquitous environment, home networking middleware should be able to recommend home services based on a user's interests and efficiently manage information on service usage profiles for the users. Therefore, USN (Ubiquitous Sensor Network) technology, which recognizes and manages a appliance's state-information (location, capabilities, and so on) by connecting RFID tags is considered. The Intelligent Multi-Agent Middleware (IMAM) architecture was proposed to intelligently manage the mobile RFID-based home networking and to automatically supply information about home services that match a user's interests. Evaluation results for personalization services for IMAM using Bayesian-Net and Decision Trees are presented.

Keywords—Intelligent Agents, Home Network, Mobile RFID, Intelligent Middleware.

I. INTRODUCTION

THE materials now being dealt with in the networking environment are not only books, magazines, and other materials printed on paper, but also electronic and/or digital materials like CD-ROMS, DVDs, e-journals, e-books, and so on. Furthermore, along with the rapid advancement of information technology, a lot of home networking projects [1, 2, 3, 4, 5] have been launched and more and more library services are provided on the Internet. Now the libraries are changing from the traditional "tosho-kan (book/liber-house)" to "information-kan."

Even though more and more patron services are required and libraries are hoping to do that, the given resources of libraries, such as the number of staff and constructing digital libraries, are generally very limited these days.

To solve these issues, by attaching RFID (Radio Frequency Identification) tags to materials, libraries and librarians get great benefits, such as a reduction of the staff's time for inventory and the check-in/check-out of books [6, 7].

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Comparing the inventory time for books with RFID tags and those with barcodes, the former is estimated to be some twenty to thirty times faster than the latter, By installing self check-out machines, the number of staff at the circulation counter may be reduced to half. RFID technology has been applied to the home networking environment in recent years. RFID technology describes the use of radio frequency signals to provide automatic identification of items. RFID is a flexible technology that is convenient, easy to use, and well-suited for automatic operation. RFID can be supplied as read-only or read/write, does not require contact or line-of-sight to operate, can function under a variety of environmental conditions, and provides a high level of data integrity.

Because of these advantages, RFID technology is widely used in the home networking environment. For example, digital libraries have decided to utilize RFID to replace bar codes. Middleware technology to manage many kinds of books in an RFID home networking is being actively studied. RFID middleware technologies such as the LibBest Library RFID Management System [4], which supports the simplification of patron self check-out/check-in and high-speed inventory and identifies items that are out of their proper order, and Intellident [5], which is used for managing media data in a home networking, have progressed in several projects. Through the use of this RFID middleware, such as LibBest and Intellident, an RFID-based home networking environment only manages book and materials; such home networking middleware does not automatically recommend information about books that might match a user's interests, and cannot efficiently support, manage, and retrieve information about a book for user. For such reasons, most of the future work for home networking middleware for RFID-based home networking environments will involve smart middleware that supports the ability to efficiently and easily manage and offer books to users. Therefore, the overall design work considers USN [10, 11] technology, which recognizes and manages a book's state-information (such as a book's title, author, ISDN, and so on) by connecting RFID tags, to solve RFID technology's weakness. IMAM (Intelligent Multi-Agent Middleware) was proposed to efficiently manage books and support intelligent services (automatically recommending interesting books to a user and retrieving a book's information, such as its location, author, title, etc.. through an RFID tag attached to the book) using Bayesian-Net[16] for mobile RFID.

II. RELATED WORK

Digital Libraries provide a structured way of displaying information over networks, such as the internet. Unlike the

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internet, which is typically clogged with irrelevant and unhelpful information, digital libraries provide access to edited and categorized content. Not only does this make it easier to locate content, but is also reduces the cost incurred in printing and distribution. For example, the major purpose of this research is to provide the contents of a home networking to mobile users. This research identifies issues that arise when users are mobile, classifies queries that are specific to mobile users, and introduces an architecture that supports flexible and transparent access to digital libraries for mobile users through the use of RFID tags [15].

A. RFID/USN

A USN is constructed by the addition of an electronic tag, which is attached to objects to sense the surrounding environment. It manages information (such as a book's title, author, ISDN and so on) through a network. The USN expands the information-oriented society from a strictly human centered paradigm to one including objects [10].

USN technology is the combination of wired and wireless networks consisting of an electronic tag, reader, middleware, and an application platform. Specifically, 900 ㎒ RFID technology provides a comparatively long reading range (10m) with cheap, passive tags requiring no battery. RFID Technology will become a core technology that can be used widely in the fields of logistics, distribution, pharmaceuticals management, and military logistics in the future[10,11].

B. Mobile RFID

A mobile phone integrated with RFID can activate new markets and end-user services, and can be considered as an exemplary technology fusion. Furthermore, it may evolve its functions as an end-user terminal device, or 'u-device (ubiquitous device)', in the world of ubiquitous information technology [15]. Actually, a mobile RFID phone may represent two types of mobile phone devices; one is an RFID reader equipped mobile phone, and the other is an RFID tag attached mobile phone. Each type of mobile phone has different application domains, for example, the RFID tag attached phone can be used as a device for payment, entry control, and identity authentication. A feature of this application is that RFID readers exist in fixed positions and recognize each phone, to provide user specific services, like opening doors.

C. HIML (Human Interaction Markup Language)

HIML (Human Interaction Markup Language) is a markup language that is based on XML. An HIML document can be used for the expression and transmission of various data information for the efficient management of context information in a ubiquitous computing system [13]. Context is classified as location context, time context, environment context, user context, device context, and other context in researches about context-awareness [12]. Context is classified into two types, user and adminUser. This classification is a more simple and efficient organization for an intelligent service. User context expresses a user's profile information

and a user's condition information. Device context expresses each appliance's or sensor's information. Finally, proximity context expresses the distance between a user and device.

III. ARCHITECTURE OF MOBILE RFID-BASED HOME NETWORKING ENVIRONMENT

This section introduces the proposed architecture of the mobile RFID-based home networking environment. This architecture provides services and supports flexible and transparent access to digital libraries for mobile RFID users through the use of mobile RFID and RFID tags, which allow the storage, retrieval and transmission of a book's information to a user in a home networking.
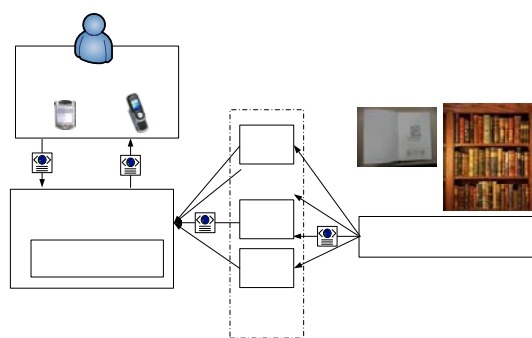

Fig. 1 Architecture of Mobile RFID-based Home networking Environment

Fig. 1 is the design for an architecture to efficiently manage and support intelligent services (automatically recommend interesting books to a user and retrieve information about that book) in a mobile RFID-based home networking environment. To manage several books and digital materials, a user utilizes two connection-systems. The first method makes it possible for a user to manage several books and digital materials, after the user is authenticated through a web browser that uses a web service. The second method is an HIML document that is transmitted using a mobile RFID for the user. RFID sensors, which are attached to all books and digital materials in order to sense the state of the books and digital materials, periodically send the state of the books and digital materials. This state-information is transferred to RFID readers. The Intelligent Multi-Agent Middleware collects this data from the RFID readers, analyses the data, and sends the information about books and digital materials that might interest the user, in order to provide an optimal environment for the user of the home networking environment.

A. Service Scenario of Intelligent Multi-Agent Middleware Mobile RFID-based Home Networking

Intelligent Multi-Agent middleware automatically supports efficient and easy management and lending of books/digital materials to mobile RFID users based on the proposed service scenario that follows:

    1) User A steps into the Library
    2) Intelligent Multi-Agent senses mobile RFID of user A
    3) User A's basic information (id, name, and so on)

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4) Intelligent Multi-Agent automatically sends top 5 books in interesting book/ digital material's category of user A, which are analysed by Pattern Agent, to mobile RFID of user A.

- Lending book's information (book's location, ISDN, author, etc..) of user A
- If user A has borrowed books in past, send this information
- After analysing borrowing preferences through Pattern Agent, send assumed Top 5 books to user A's mobile RFID
  - ♦ If user A inputs a keyword, Intelligent Multi-Agent sends appropriate keyword-books, from the results determined by the analysed keyword and user A's borrowing preferences established through the Pattern Agent, to user A's mobile RFID

5) User B steps into the Library

6) 2)~4) steps repeatedly perform

IV. INTELLIGENT MULTI-AGENT MIDDLEWARE FOR MOBILE RFID-BASED HOME NETWORKING ENVIRONMENT

Lately, active research has been taking place on projects involving RFID middleware, which supports the management of books and digital materials for users in RFID-based home networking environments. For example, progress has been made on several projects involving RFID middleware technologies for the home networking, such as the LibBest Library RFID Management System, which supports the simplification of patron self check-out/check-in and high-speed inventory and identifies items that are out of proper order, as well as Intellident, which is used for managing media data.

However, although RFID Middleware technology, such as LibBest, Intellident and so on, is able to manage several books and digital materials in an RFID-Based home networking environment, the agents don't support intelligent technology. This means that RFID middleware, such as LibBest and Intellident, for the RFID-based home networking environment, only manages books and digital materials. It does not support home networking middleware that can automatically recommend books that match a user's interests, and does not efficiently manage and retrieve information about a book for a user. For such reasons, most of the future work for home networking middleware for RFID-based home networking environments will involve smart middleware that allows the efficient and easy management and offering of books to users.

Therefore, IMAM is needed to support the easy management and offer autonomous home services to users, under a mobile RFID-Based home networking environment. Accordingly, an agent that can autonomously support a book's information (title, location, author, and so on) instead of a mobile RFID user is necessary in order to save the user time and effort through a Monitoring Agent and Pattern Agent.

A. Architecture of Intelligent Multi-Agent Middleware

Since all the information for books and digital media are defined in the Intelligent Multi-Agent Middleware, if an aware mobile RFID wants to search for a keyword, manage a book/digital material, and lend a book/digital material in a home networking, it has to look-up the management variables (lend, location-tracking, title, lend-history, ISDN etc..) for the target books and digital media in the Intelligent Multi-Agent Middleware. The Intelligent Multi-Agent Middleware can then invoke control functions using a remote control method invocation. The following is the execution procedure to support intelligent service for a user.
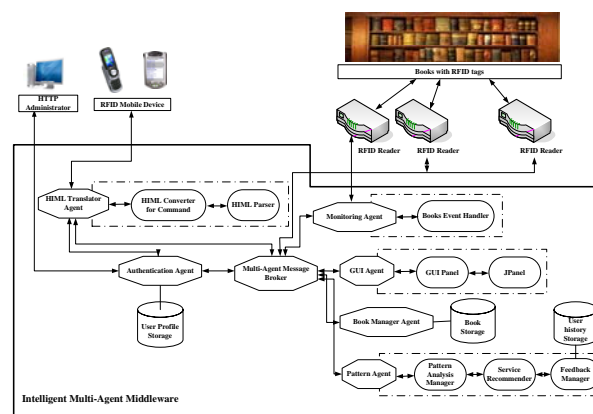

Fig. 2 Architecture of Intelligent Multi-Agent Middleware

As shown in Fig. 2, to manage books with RFID tags, a user uses two connection systems in the Intelligent Multi-Agent Middleware. The first method makes it possible for a user to borrow and search for books and digital materials, which have attached sensors, in the Intelligent Multi-Agent Middleware, after the user is authenticated through a User Authentication Agent, which utilizes SSO (Single Sign-On) [14], in a web browser. The second method uses an HIML document transmitted using a mobile RFID through a User Authentication Agent, using a network (sensing, TCP/IP, and so on) for an HIML Translator approach, which after parsing approaches the Multi-Agent Message Broker.

To receive home networking service through a web or mobile RFID, it accepts data on access privileges by a mobile RFID in a User Profile Storage through the user ID of an Intelligent Multi-Agent middleware aware user mobile RFID. After the Multi-Agent Message Broker receives the id of a user's mobile RFID, it looks for appropriate services through book information and the Pattern Agent and supports these intelligent services for the user.

The Intelligent Multi-Agent Middleware observes the states of the books and digital media through the Monitoring Agent. An agent that can autonomously manage any information change for a book or digital material instead of the user is necessary in order to save the user time and effort. This agent must continuously collect data from the RFID sensor Tags attached to books and digital media, analyse the collected data,

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and find out the inclinations of the user, based on the analysed information. If the Books Event Handler finds information about a book event, it modifies the book information in Book Storage through the Multi-Agent Message Broker and Book Manager Agent.

Recent RFID-based home networking middleware only manages books and digital materials, it does not support home networking middleware that automatically recommends books that may interest the user, and does not support the efficient management and retrieval of book information for a user.

However, the proposed Intelligent Multi-Agent Middleware solves problems like this through a Pattern Agent. When the Intelligent Multi-Agent Middleware recognizes a user's mobile RFID through a Pattern Agent, it efficiently manages books or digital materials and supports intelligent services (automatically recommending interesting books to the user and retrieves information about a book, such as its location, author, title, etc.. through the book's attached RFID tag) for mobile RFID users in the Mobile RFID-based home networking environment.

The Multi-Agent Message Broker implements generic agent functionality for sending and receiving messages. The GUI Agent is essentially a GUI application that displays tabbed panes for each connected agent. The Book Manager Agent manages each book and digital material's information (location, title, ISDN, author, lend service and so on) and periodically updates the information and stores this changed information in Book Storage. The Authentication Agent utilizes SSO and the agents in the Intelligent Multi-Agent Middleware maintain trust-relationships.

B. HIML Translator Manager

The HIML Translator Manager transmits context information in an HIML document to a mobile RFID. Or it receives control messages from a mobile RFID. The HIML document is interpreted in the HIML Parser and the data type is converted for a mobile RFID in the Context Transformer. The converted context data is transmitted to a mobile RFID immediately. A user can recognize the current state of books and give a book's information to the mobile RFID of a user by the Context Agent of the mobile RFID. If a user tries the personalization service, which is supported for the user by the Intelligent Multi-Agent Middleware, the Context Agent sends a control message and user context data to the Communication Manager for feedback. The control message and user context data are converted to an HIML document by the HIML Converter. The HIML document is sent to the Intelligent Multi-Agent Middleware again.

C. Evaluation Results

As home networking deployment evolves, personalization services are gaining more interest among researchers, resulting in the appearance of quite different approaches: Bayesian network techniques, decision trees [17] and etc. Among all these techniques, the Bayesian network was selected to infer new data from the known information, since they allow to

represent uncertain and incomplete knowledge by means of probabilistic modelling.

Fig. 3 shows the Pattern Agent Architecture, which analyses the borrowed book's category for a user that wants to see the book's category, input-keyword, and so on, to support personalization service for a user. For example, if a user doesn't find a book through a keyword search, the Pattern Agent recommends books and digital materials to a user, according to an analysis of a user's book borrowing pattern. If a user borrows another book that wasn't recommended by the Pattern Agent, the Pattern Agent records the user's new pattern in User history storage.
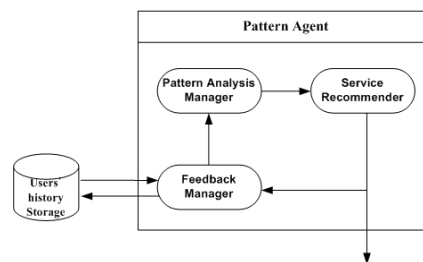

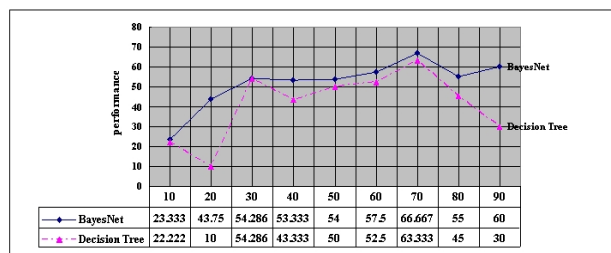Fig. 3 Architecture of pattern Agent in intelligent Multi-Agent Middleware

Fig. 4 Performance results of personalization services using Bayesian network and decision tree

Fig. 4 shows performance result of personalization service using Bayesian Network and Decision Tree. The experiments were conducted with proposed personalization services based on data sets from two hundred people. The x-axis of Fig. 4 shows the percentage of test data for learning phase, i.e. 10 means that 20 data sets are used for training the learning algorithms. As show Fig. 4, according to increase number of learned data in IMAM, performance of personalization services based on Bayesian network is higher than Decision Tree for all number of users.

First of all, there are two possibilities to assign weights to the Bayesian network used:

- To introduce these weights manually. In this case we should consider some reliable source that provides the necessary information.
- Learn the weights from previous recommendations.

Taking into account the non-existence of reliable source of information, we have considered the second option explained above. For that reason, we need a storage that contains information about all the users in the system, such as their user profiles and the contents recommended successfully in the past,

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that is, the books that have been suggested by the IMAM and selected by the user.

Therefore the training set contains the different ontological categories of home networking contents considered in the user profiles (referred to the books read in the past) together with the personal data of the users. Also, it intends to show an example of proposed IMAM described, that can be extrapolated to a more complex scenario where all the available information is accessible.

Fig. 5 View provided Personalization service in mobile RFID

Fig. 5 shows result of personalization service which is provided by IMAM.

V. CONCLUSION AND FUTURE DIRECTION

This paper proposes IMAM for a mobile RFID-Based Home networking Environment and describes the execution result of personalization service through Pattern Agent in IMAM environment.

An IMAM supports the efficient management of several books and digital materials for users of mobile RFID in Home networking Environments. Accordingly, an agent that can autonomously support a book's information (title, location, author, and so on), instead of a mobile RFID user, is necessary in order to save the user time and effort through a Monitoring Agent and Pattern Agent. And according to increase number of learned data in IMAM, performance of personalization services based on Bayesian network is higher than Decision Tree for all number of users.

Some of the most important future work in out project involves a user-based context awareness study and more efficient algorithms study to efficiently support personalization service for a user.

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