Context-Aware and Adaptive Universal Home Network Middleware for Pervasive Digital Home Environment

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Abstract

Users will be able to access ubiquitously present appliances anywhere and anytime through pervasive digital home environment. For this, we need middleware that provides a high-level abstraction for zero-configuration and interoperability among middleware, makes each appliance's behavior context-aware, and supports a variety of adaptive behaviors. This paper identifies context-aware and adaptive middleware, called Universal Home Network Middleware, for the future pervasive digital home environment. It provides a desirable environment that supports adaptability and dynamic composition through appropriate high-level abstraction.

I. INTRODUCTION

Over ten years ago Mark Weiser identified the goal of future computing to be ubiquitous computing. In the near future, computation and communication capability will be embedded in virtually every appliance [1]. Users will be able to access ubiquitously present appliances anywhere and anytime. Accordingly, pervasive computing has potential to radically transform the way people interact with computers. The key idea behind pervasive computing is to deploy a wide variety of appliances throughout our living and working spaces [2][3]. Many researchers recognizes the digital home as starting point of pervasive computing.

As people move throughout physical world and an appliance's execution context changes all the time in pervasive digital home environment, middleware needs to embrace contextual change. Users also expect that their appliances and applications just plug together. Thus, middleware needs to encourage dynamic composition and not assume a static computing environment with a limited number of interactions [2][3]. Since embedded appliances have limited resources and functions, they cannot provide effective services without cooperating with other appliances. The increasing diversity of appliances implies that different middleware will be in use. It is highly improbable that there will be, in the near future, single dominant middleware that would be good enough for different appliances. Pervasive service requires interoperability among middleware, high-level abstraction, zero-configuration, and context-awareness [1][2].

However, contemporary middleware — HAVi [4], Jini [5], and UPnP [6] — typically assume a static and well-administrated computing-environment, require that applications are well-behaved, and closely couple devices to each other [2][5]. Moreover, people need to adapt the system instead of the applications adapting for changes. It is not easy to develop a pervasive service to support such adaptability and dynamic composition based on currently available digital home middleware, which do not provide a sufficiently high-level abstraction to dynamically compose appliances [2][7].

Therefore, we need new middleware with which we can integrate any middleware in a simpler way, and deploy pervasive digital home services without the conscious of diversity of appliances. Also it supports adaptability and dynamic composition through appropriate high-level abstraction. To accomplish this goal, we propose new middleware guaranteeing seamless interoperability of appliances and deployment of services under heterogeneous middleware with considering contextual change.

In this paper, we identify context-aware and adaptive Universal Home Network Middleware (UHNM) enabling seamless service provisioning in heterogeneous, dynamically varying future pervasive digital home environment. Our proposed UHNM architecture is consisted of following components; Adaptor, Messaging Layer (ML), Event Manager (EM), Configuration Manager (CM), Resource Manager (RM), Device Manager (DM), Service Manager (SM), and Virtual Proxy (VP). The rest of the paper is organized as follows. We discuss the related works on digital home middleware in Section 2. In Section 3, we present the design issues, and describe the details of the UHNM architecture and experiments for verifying the feasibility of the proposed UHNM in section 4. Finally, in Section 5, we conclude the paper with future work.

II. RELATED WORKS

There are several approaches to ensure the interoperability among the different home network middlewares. They are one-to-one and one-to-many protocol conversion approaches. HAVi-to-UPnP bridge at Thomson provides the interoperability between UPnP and HAVi. It solves some problems with diversification of middleware. But, these are not enough to develop a single bridge that connects two specific middleware one to one, when new middleware will be developed one after another [8]. Framework for Connecting Home Computing Middleware at Waseda University enables any appliances under any middleware's control to communicate any other appliances. It uses and deploys service of home without special conscious of diversification of middleware. The drawbacks of this are the it cannot generate services dynami-

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cally by combining any functions of any appliances [9]. Context-/Location-based Middleware for Binding Adaptation (Colomba) Framework automatically updates mobile user references to needed resources whenever a user moves, and dynamically selects and enforces the most suitable binding strategy. Colomba operates according to dynamic environmental conditions, administrator management requirements, and user profiles [7].

III. DESIGN GOAL AND UHNM ARCHITECTURE

In this section, we describe the goal of UHNM architecture and details of its implementation. Also we explain the experiments conducted to verify the feasibility of our proposed UHNM.

3.1. Design Goal of UHNM

As we mentioned earlier, future pervasive digital home environments need to be context-aware and adaptive. Accordingly, we need new middleware that provides a high-level abstraction and zero-configuration, and makes each appliance's behavior context-aware and supports a variety of adaptive behaviors – changes in the execution and communication capabilities, efficient use of available communication resources, and location of mobile users.

Our UHNM provides a desirable environment in which an appliance can interact with and detect other appliances under different middleware through considering the circumstances change. It also appropriately deploys certain services, which composes functions of multiple appliances, and new middleware can be easily integrated. Also it supports adaptability and dynamic composition through appropriate high-level abstraction.

3.2. Implementations of UHNM

Fig 1 shows the proposed UHNM architecture. Every appliance in the pervasive digital home is physically connected through the home network – IEEE1394, 802.11a/b, Power-Line, and Ethernet. UHNM supports several sub-middleware defined by several consortiums – HAVi, Jini, UPnP, and LonWorks. They provide the logical connection between appliances based on same middleware. Our UHNM architecture is consisted of following components; Adaptor, ML, EM, CM, RM, DM, SM, and VP. UHNM provides the seamless connection among heterogeneous sub-middleware. Components for zero-configuration are ML, EM, CM, RM, and DM, and components for interoperability among heterogeneous middleware are Adaptor, and VP. Components for context-aware and adaptability is SM.

An Adaptor converts the sub-middleware protocol to the UHNM protocol to guarantee seamless interoperability among heterogeneous contemporary middleware. All UHNM components communicate using a message passing mechanism through ML, and EM delivers events to the other components, when the status of networks is changed. CM serves as a directory service to provide zero-configuration as a result of the addition or removal of an appliance. The RM allows services to reserve and release any appliance. The DM is responsible for installing and removing VP, a virtually pre-defined appliance control module, which abstracts and represents a single appliance, and is the source of interoperability and deployment in accommodating new appliances and features into future digital home networks for context-aware and adaptive pervasive services. Through these VP objects, each service can access other appliances transparently as appliances are implemented on the same middleware.

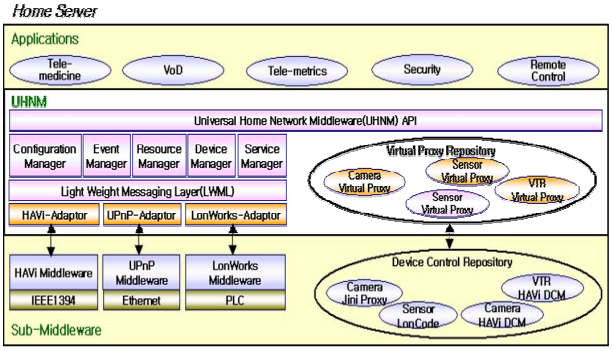

Fig 1. Universal Home Network Middleware Architecture

The SM invokes and deploys the services, and provides the environment for dynamically composing functions of appliances according to user's location and circumstances change. To enhance adaptability in digital home, each appliance is designed independently and the service requirements may be specified separately. For this, our middleware lets service provides express composition strategies at a high-level that are cleanly separated from service code; changes in composition strategies thus require no intervention in the application logic. SM request RM to reserve needed appliances with a service script in order to acquire all appliances. The SM allows the adaptation service to dynamically combine appliances based on composition strategy as a result of user mobility, and changes of digital home. For this, SM utilizes information on appliances and circumstances change from CM, the list of appliances used by the service and composition strategy from service script, and user's location from user.

3.3. Its Experiments

In order to verify the feasibility of the proposed middleware, we've implemented an event-based surveillance service using a HAVi-camera and HAVi-display on IEEE1394, a LonWorks-motion sensor on PLC, and a Jini-display on TCP/IP. UHNM and several sub-middlewares are executed over home server, which is the central of home network, and manages and controls the appliances on the home network without user intervention. We have implemented our home server with JDK1.3.1 and Linux.

A user point PDA to select the room where he is. Then SM dynamically combines the HAVi-camera and the display-appliance nearest user that receives and displays the captured-image from HAVi-camera. If a user move to different room, he switches the location by pointing PDA. As soon as SM receives the change of user's location, existing interactions between the appliances will be hand over to the new display-appliances resulting in uninterrupted use of service according to change of user's location. Fig 2 shows the test-bed.

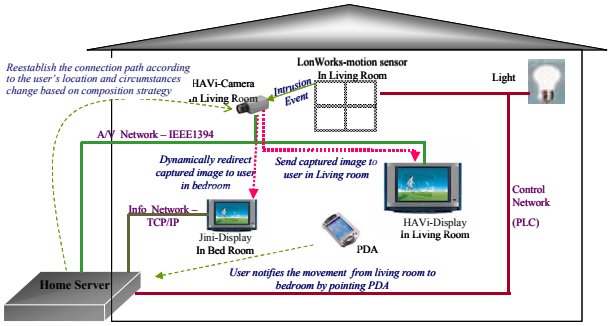

Fig 2. Heterogeneous Home Network Middleware Testbed

This experiment shows that UHNM provides context-aware and adaptive service with considering user's location and circumstances change through dynamically combining. Moreover, UHNM provides users with single image view of digital home, and an appliance can communicate with other appliances under different middleware.

IV. CONCLUSIONS AND FUTURE WORKS

In this paper, we present the details of UHNM and its implementations. UHNM architecture provides zero-configuration, and high-level abstraction, and makes each application's behavior context-aware and adaptive. Therefore, UHNM enables the deployment of home network services, and dynamically creates new services by combining the functions of appliances without being limited by the middleware. Moreover, UHNM architecture ensures seamless interoperability among heterogeneous home network middleware, and provides scalability by simply adding an adaptor to new middleware.

In the near future, the explosion of mobile appliances will have conditioned users to expect access to services anytime and anywhere. We extend our prototype UHNM to the mobile Internet environment with automatically determining the location of users and appliances. In present, UHNM only supports the simple composition by considering the user's location and circumstances change without considering the user preference or behavior. Therefore, we will include mobile agent technology in UHNM to provide enhanced adaptation service by considering user preferences and user behavior.

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