Personal Environment Service based on the Integration of Mobile Communications and Wireless Personal Area Networks

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ABSTRACT

The vision behind the Personalized Living Environment (PLE) is that of recreating a user's customized living or working surroundings in accordance with user-defined settings and in response to the user's mobility. Concepts such Ambient Intelligence, Home Network, and Personal Environment Service (PES) could be instrumental in realization of PLE.. Indeed, integration of elements of these three technologies may be the catalyst for deployment of PLE and an enabler in attracting industrial attention. Moreover, underlying technologies related to the above concepts are envisioned to play a key role in the implementation of PLE, including mobile communications supported by ubiquitous infrastructure and Wireless Personal Area Networks. In this paper, we present a simple PES network architecture and its underlying network technologies, and we discuss a set of potential services of PES. We also compare PES with other related concepts capable of supporting the PLE vision.

INTRODUCTION

The concept of *Ubiquitous Computing* [1], which was introduced in 1991, stated that "specialized elements of hardware and software, connected by wires, radio waves and infrared, will be so ubiquitous that no one will notice their presence." Since then, numerous research and development projects have been striving to implement this vision. However, because of the broad scope of the concept, there is little synergy among the proposed services. Thus, it is difficult to make a strong business case for this concept. And lacking the business case, many of the *Ubiquitous Computing* services remain at the research trial level, without progressing into commercialization.

Since its introduction, several other concepts similar to the Ubiquitous Computing have been proposed, such as the *Pervasive Computing* concept, which is defined as integration of distributed communication system and mobile computing. Another concept, the *Location-Based Service (LBS),* advocates support of services depending on the present location of a user. Examples of this concept include requesting the location of the nearest gas station or automatically providing advertisement of an inexpensive gas station on the user's driving route. *Location-Aware Service (*LAS) is a service that, based on the detected user's location, modifies the settings of the user interface and the functionality of the user's computer terminal. According to the *Context Aware Computing (CAC),* introduced by Schilit [2], software adapts its function according to the location of its execution, the collection of accessible nearby users, hosts, and devices, as well as to the changes in these factors over time. Finally, through the concept of *Ambient Awareness*, a personal computing device, while possibly unattended by a user, processes application-specific information, taking the current user preferences and his/her state-of-mind into account. The basic idea behind all of these concepts is to provide a user with a versatile and broad range of computing services, which depend on the user's and the system's parameters and in accordance with the user's explicit or implicit needs and desires. To realize these concepts, appropriate underlying technologies are essential in implementing the elements of these concepts and in making the user's environment intelligent, automated, and personal.

In Europe and in the United States, there has been a lot of research and development activities related to *Ambient Intelligence* (*AmI*) projects. The goal of the AmI concept is to make living spaces optimized for users [3, 4]. The underlying technology is based on the ability to collect information of users by means of sensors located within the user's space. This information is then communicated to home appliances that are in the vicinity of the users, to automatically construct the personal environment appropriate for the users.

The *Home Network* (*HN*) concept supports a home-based server which controls home appliances to provide a convenient ambiance for to home occupants [5]. The proposed underlying technology is an all-wireless solution using the IEEE 802.15.3a (the Wireless Personal Area Network) and the increased-capacity IEEE 802.11n standards**.**

The *Wireless World Research Forum* (*WWRF*)[1], which studied the architecture of future mobile communication services, anticipated the saturation of provider-oriented mobile services and has considered user-centric mobile services. From the view point of communication system, individual-centric (I-centric) services require ambient awareness, personalization, and adaptiveness [6].

Following the above trends, the *Personal Environment Service* (*PES*) has been proposed which constructs personalized, intelligent, and automated Personal Living Environment (PLE) through utilization of the *Wireless Personal Area Network* (*WPAN*) and the *Wireless Body Area Network* (*WBAN*) technologies, and by using the mobile phone as a service coordinator [7, 8]. In particular, PES relies on technologies such as short-range radio communication, mobile communication networks, and the Internet. In this paper, we present the PES concept, propose a simple network architecture, and discuss a number of application services. We also compare PES with other related concepts capable of supporting the vision of PLE.

ENVIRONMENT MOBILITY SERVICES BY MOBILE COMMUNICATIONS NETWORK

Since the *Personal Environment Service (PES)* uses mobile communications and mobile networks, we start by briefly surveying the trend of past and current mobile communication services. One possible way for characterization of mobile services is from the viewpoint of communicating entities [7]. The *Human-to-Human interaction mode* is a basic voice-based mobile communication service. To address the need for variety of search-based mobile services, *Human-to-Equipment interaction mode* was developed, which is supported mainly by data communications, such as Internet web surfing and video-on-demand services. The most advanced mode of communication is the *Equipment-to-Equipment interaction mode*, which allows, among other features, for distributed data processing using new technologies, such as agent-based processing. This latter interaction mode could be, for example, implemented by a widely deployed sensor network with context-aware data routing. In this mode of interaction, through autonomous interchange of information, equipment should continuously undergoes reconfiguration, as to create a more efficient processing system and a more suitable environment for the users. Typically, modifications to the environment should not require user's intervention, but should be done automatically and transparently to the user. Rather, the involvement of the user should be limited to the initial configuration of the network of sensors and actuators of the electronic equipment and the associated information databases. Technologies to support elements of such an environment have been already

[1] The *Wireless World Research Forum* (*WWRF*), a global telecommunication organization founded in 2001, has the goal of creating future strategic research directions for academia and industry in the field of wireless systems and networks. WWRF is a contributor to numerous other standardization organizations, such as ITU, UMTS Forum, ETSI, 3GPP, 3GPP2, and IETF.

studied; e.g., Home Network of electronics, RFID for mobility management of users, and context-aware protocols. However, those elements were not developed for integrated operation between the equipment and the human operator, but rather their designs were primarily focused on the configuration of the functionality of a particular piece of equipment, ignoring the human operator's and the possibly changing-in-time individual needs and preferences. Fig. 1 shows the position of *Ubiquitous Service Network* (USN) as part of the evolution of selected wireless technologies..

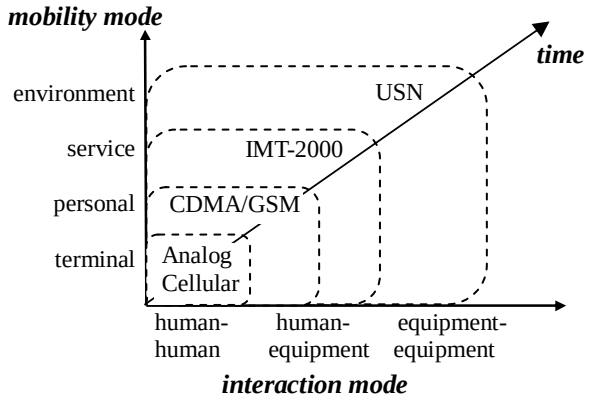

Fig. 1: The evolution of mobile communication services for various interaction and mobility modes

Mobility-supported services are among the most important and the most challenging elements of wireless mobile communication systems. *Terminal Mobility* allows users with untethered equipment to travel during a session (e.g., conversation) while supporting the basic communication services. Another mobility mode, *Personal Mobility*, allows a user to use available equipment in the current user's vicinity. Personal Mobility could be implemented, for example, through the use of a *SIM* (*Subscriber Identity Module*) card for *GSM* (*Global System for Mobile Communication*) or *UIM* (*User Identification Module*) for IMT-2000. *Service Mobility* is the third, relatively newer mode of mobility support. An example of Service Mobility is *VHE* (*Virtual Home Environment*), which provides for personally customized mobile phone service. When a user roams to a visited network, the same user's interface as the one in the user's home network is recreated within the visited network.

By combining communication services with mobility services, we propose a new mobility mode, the user's *Environment Mobility*, which relies on user's location and Equipment-to-Equipment interaction mode. We term this service *Personal Environment Service* (*PES*). While a user moves within his/her home, within an office, in a vehicle, or outdoors, the environment's aspects (such as temperature, humidity, lighting, music, ambient displays, computing services, etc) are optimized and customized to the user and follow the user in his/her movements. In other words, PES recreates the aspects of the user's environment in response to user's mobility. By leveraging from the advances in communications and in mobile services, PES, or a subset of its features, could very well become the next generation service of wireless and mobile networks.

In realization of PES, the role of mobile communication device (e.g., a blackberry) is of central importance. These days, essentially everyone carries at least one mobile communication device, and such devices are equipped with a display means, an input means, and outfitted with high performance microprocessors. Most users are accustomed to charging their communication device daily, thus shortage of battery power may not be a critical issue (although it still remains a major consideration). Because of those and other features, it is anticipated that the personal mobile communication device will play a key role in the realization of the PES concept.

THE NETWORK ARCHITECTURE OF THE PES SYSTEM

Majority of people are quite particular about their living and working environment; we want our home and office environments to be set up according to our unique preferences and our mental and emotional states at any particular time. This usually makes us comfortable and pleased, increasing our level of relaxation at home and our work efficiency at our workplaces. It is important to note that the desired settings of our environments are dynamically changing with time. Furthermore, those settings strongly depend on our particular location at a particular time; i.e., an office, a home, a car. Thus, to support the goal of improving our lifestyles by personalization of our environments, as we physically move, the environment should be continually reconfigured and recreated; i.e., the environment should "move with us." This is the basic idea behind the Personal Environment Service (PES).

PES dynamically, automatically, and intelligently reconfigures the electronic, electrical, and mechanical equipment surrounding a user according to his/her preferences and based on the current user's location and his/her current mental/emotional status. The preferences could be stored in the network as *Personal Environment Profile (PEP)*.

Although PES is related to other studies of self-(re)configuring equipment surrounding users, such as the *Ambient Intelligence* and the *Organic Computing* concepts [9], nevertheless, PES is broader than these concepts. In particular, PES can provide a feasible and, indeed, a practical solution based on the current wireless communication technologies or technologies that will be developed in the near future. Similarly, PES is more extensive than the concept of Home Network. The latter employs a home server as the service coordinator together with network infrastructure and requires location identifiers to provide personalized environment services to each user. Overall, the concept of PES represents a new mobile service, even though some elements of the PES concept have been previously known, alas as separate systems. For example, while the main purpose of Context Awareness is to construct database systematically by acquiring sensing information about the surrounding environment, PES is also capable of controlling (modify, reconfiguring, etc) the surrounding environment. As such, the functions and performance of PES can be significantly expanded by maintaining (even intermittently) connectivity to wide-area wireless/wireline communication networks. Fig. 2 depicts a vision of the PES concept [7].

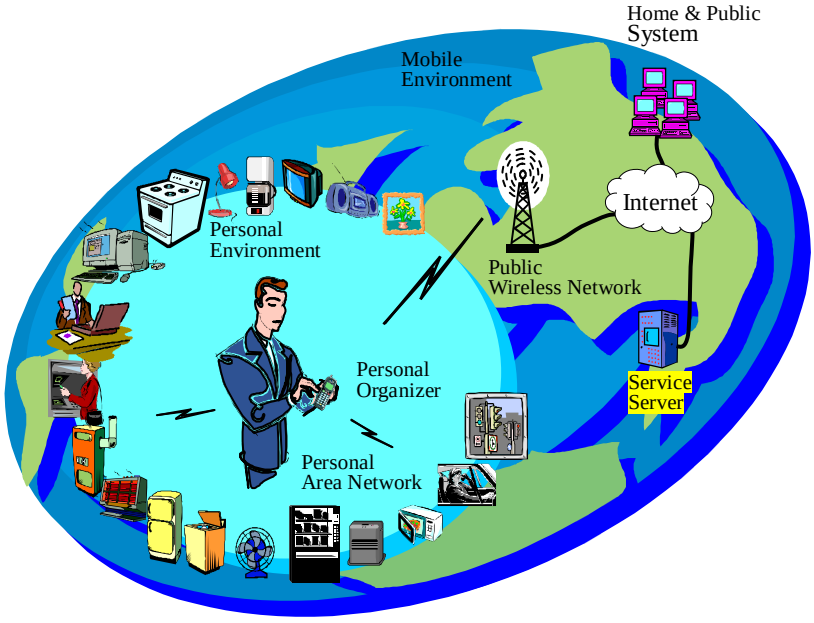

Fig. 2: The vision of the Personal Environment Service concept

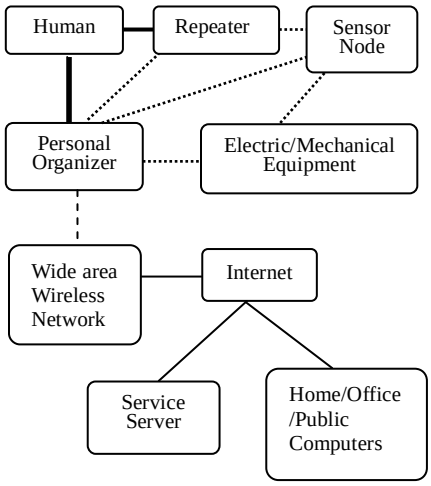

Fig. 3: The reference model of PES network (bold solid line: direct contact; solid lines: wired connections; dashed lines: wide-area wireless connections; dotted lines: short-range wireless connections)

The reference model of PES network is shown in Fig. 3. PES system consists of a *Personal Organizer (PO)*, a set of electronic/electrical/mechanical appliances, wide-area wireless/wired communication networks, a Service Server, and an optional repeater. Though the focus of PES is on the user, the service operation is governed by the PO, which is implemented within the mobile communication device carried by the user. Through a hook up to a wide-area wireless network, the PO connects to the world through the Internet. The Service Server is a software application which creates executable instances within the network or on other equipment pieces. Service Server should be implemented using the Semantic Web or Ontology technologies to provide intelligent environment services for users and synergy with other technologies.

The mobile communication device stores the user preference information, and communicates using short-range and wide-area wireless technologies. It performs the functions of security, such as authentication. Each electric and mechanical equipment piece contains a short-range wireless communication module, a personal preference recognition module, and an authentication module. These modules can exchange information with sensor nodes located around them and with the PO. The PO controls the function of the equipment and the equipment settings. Each sensor nodes comprises a sensing module and of a short-range wireless communication module. The Service Server includes a service coordinator module, which is used to construct the user-preferred environment by cooperation with the PO, and of a location-based module, which traces user's location and supports LBS. The PO, using its short-range wireless communication module, exchanges information with the equipment surrounding the user and the sensor nodes. The service range of PES depends on the communication range of the PO. When the communication range is short, employing multi-hop communication technology can be a useful approach. The PO collects data from the user and information about the environment by using the various physical equipment interfaces and by communicating with the sensor nodes. Using this information, the preference profile of the user (the PEP) is then intelligently updated. When there are several users in the same environment, their POs negotiate the values of the joint configuration parameters by exchanging the PEPs among the POs.

The PO and the Service Server can implement the PES profile management and manage other PES-related information from the home and the public databases. The PO and the Service Server also monitor user's

feedback information related to the configured environment, analyze the information, and control the environment. Overall, the PO recommends proper environmental services and parameters' settings for the user. The PO then reconfigures the environmental services in advance of the user's movement.

In order to continuously reconstruct the user's preferred environment as the user moves, large amounts of data may need to be communicated. For ubiquitous service system, the communication should be as simple as possible to minimize the cost and the power consumption. Consequently, given the current technological state-of-the-art, use of the Internet protocols in the communication modules may not be an appropriate solution. However, the hope is that with technological advances, eventually every node will be able to support the Internet Protocol, which will then provide seamless connectivity between the public communication network and the end nodes. Thus, we envision that in the long run, the communication between wide-area wireless networks and the short-range wireless communication networks will be based on the IP protocol, or possibly on its leaner version based on the requirements of the USN.

The *Human-to-Equipment interaction mode* between a user and his/her PO are implementing in several ways. The user can input data into the PO directly, or the data about the user can be collected through the sensing points on the body of the user, such as the user's mobile communication device, his/her wristwatch, or bio-sensors (for example, blood pressure meter, skin conductivity, electrocardiogram, etc.). The PO, the sensor nodes, and the electronic equipment continuously exchange environmental information among themselves.

Short-range wireless communication modules can easily adjust their radio transmission power, allowing for estimating the distance between the wireless nodes. This distance information could also be used for establishing the personal environment. For example, when a user reads a book, the nearest lamp (rather than a far away lamp) should increase its brightness. The use of relative-ranging information will be an essential component in the operation of the equipment in the user's environment.

Using this proposed architecture of PES, a sophisticated, versatile, and customized environment could be constructed for each user, which is one of the PES differentiating factors from other technologies. By employing the optional bracelet-style repeater (see Fig. 3), which is capable of relaying transmissions between the PO and the appliances surrounding the user, would allow the user not to always carry the PO on his/her body, but rather leave the PO within the user's general vicinity..

APPLICATIONS FOR THE PERONAL ENVIRONMENT SERVICE

1. Basic Personal Environment Service

- Service for the home:
  - automatic air conditioning: configuring temperature, humidity, air purity, and ventilation
  - decoration control: type of lightning and its intensity, content of electronic picture frames
  - favorite group selection: TV channel, music, cooking means
  - auto configuration of computer: power on/off, favorite web site addresses, Internet home pages, login names, passwords, monitor themes, application program porting, user attributes for application programs, volume control, e-mail configuration
  - mood control: calm mood, exciting mood, sleeping mood - according to the environment profile, the set of environmental components such as temperature, light intensity, music selection and volume, communication function (like filtering incoming calls), the content of electronic picture frames, food selection, and cooking means are configured properly.

- Service for the office and other indoor locations:
  - private assistant: selecting and providing conference material from user's computer to the meeting place
  - favorite beverage and food selection at vending machines or stores
  - location identification: indoor location identification, automatic destination guide configured on the display at the entrance to the building, elevator control, other LBS
  - automatic recognition: attendance check, entrance control, access authorization

- Services for the vehicle:
  - automatic air conditioning: temperature, ventilation
  - automatic driving mode control: seat position, steering-wheel position, mirrors' angles, pedal sensitivity, alarms settings (e.g., maximum speed)
  - favorite CD music or radio station selection
  - in-vehicle navigator control: menu configuration, favorite geographical information rendering, geographical information update, Telematics services through the PO

- Services for outdoor locations:
  - travel and location information service: electronic display guide, location of favorite services, general geographical information, transportation means and scheduling, translation to user's preferred language while traveling abroad
  - automatic street illumination control

2. Extended Personal Environment Service

- Electronic payment: mobile communication provider participating in E-Commerce business would allow credit-card-less payments with appropriate authentication and transaction approval, including fraud control
- Customer management: personalized marketing with consideration of the time and location information of users, effective service for the user in restaurants, stores, theaters, and etc.
- Personal gateway: effective and efficient communication through a small footprint devices allowing connectivity to the Internet

3. Public Personal Environment Service

- Energy savings[2] & CO_2 emission control: turning off lightning in unoccupied locations, optimal control of air conditioning and heating, T.V.s, PCs, and other equipment
- Safety service: gathering of security information at check points, bus stops, hotel and building lobbies, efficient emergency services dispatch, crime prevention, dissemination of road condition information, accident prevention and control
- Traffic information gathering: gathering of traffic information for efficient traffic control, calculating emergency routes and evaluation routes

To support the ubiquitous services, an infrastructure in the physical environment is needed. Therefore, the deployment of the ubiquitous services needs significant up-front investment. Although, from the user's perspective, the services offered by PES are very attractive and could create business for the equipment industry, the need for PES infrastructure could be a serious roadblock in having service providers and manufacturers buying into this technology.. Indeed, the up-front investment is quite possibly the major

[2] Larger than standby energy consumption

reason why this kind of service has not been yet deployed. The PES infrastructure could be utilized by both, the private and the public sectors, and could create economical stimulus. Thus to realize the concept of the ubiquitous services, there should be a coordinated strategy among the various technology players to initiate the implementation process with convincing business plan and with governmental encouragement. In general, the more attractive a service is for the users and the stronger the service guarantees are provided to the users, the faster the acceptance and the better the penetration of the services are within a user population. This, in turn, attracts more investors.

To implement the concept of PES, the required elements are the user's home appliances and his/her mobile communication device, enhanced with PES functionality. A viable path to realization of the PES concept is for the user to gradually acquire appliances with PES functionality while replacing old appliances or retrofitting them using inexpensive adaptors. Thus PES provides business for appliance manufacturers, as well as expanding the business for communication service providers. As the Service Server monitors and manages the Personal Environment Profiles, within privacy limits and with the user's consent, a communication service provider can collect information about the users' behaviors and preferences. The communication service provider can then use this information to improve the service for the users by supplying the users with wider range of service options and with better quality. Charging the PES users for the personalized environment services needs to be affordable and worthy for the users to accept and enjoy this new technology. Initial subsidy from the service provider or governmental organization might have a large impact on the successful proliferation of the PES service.

COMPARISON TO RELATED TECHNOLOGIES

The PES based on mobile communication devices and WPAN share some similarity with the concepts and the services of AmI and HN. Indeed, all these concepts share the common purpose of providing a comfortable living environment to user. Furthermore, the implementations of these concepts employ various sensors modules to acquire information, as well as the introduction of appliances with new communication functions. However, the realization methods of these concepts are totally different, thus leading to different way that services are rendered. The business models for these concepts are different too.

For example, HN services could be categorized as networking services for computing devices, entertainment devices like TVs and DVD players, communication devices like phones, and smart home appliances [5]. The comparison between the three service technologies are summarized in Table 1.

To update the user's preference information, the Service Server can update the information through monitoring the user's condition and behavior, effectively implementing system learning capability. So the user environment could be optimized even if the user could not precisely define or verbalize his/her needs or wishes. In comparison, AmI depends on versatile sensors like microphone and camera to set the user preference information, determining the correctness of the service choice by the fidelity of the sensors-obtained information. Furthermore, in spite of the convenience of this method, there are limitations in recognizing the user preferences.

In HN, the selection of settings could be done by users wearing an RFID tag and a reader being placed at the room entrances. When the user enters a room, the home server recognizes his/her identification, and the preference information is read from the tag. However, as opposed to PES, the user environment in HN is configured in, and based on, the room, rather than being based on the immediately surrounding user's space.

Comparison item	PES	AmI	HN
Service coordinator	Personal Organizer (PO)	Appliances	Home Server
Acquisition method for the user preference information	Based on preference data stored in the PO and managed by Service Server with adaptive learning capability	Self acquisition from diverse sensors and analysis using context awareness	Recognizing the information from the user tag at a room entrance
Control method for the appliances	Control using mobile communication device equipped with a WPAN module (i.e., the PO)	Self control of appliances	Control by home server
Communication networks	Convergence network of WPAN, mobile communication technologies, and the Internet	WPAN, power line communication, etc.	WPAN, Ethernet, power line communication, etc.

Table 1 Comparison of three personal service technologies

PES is user-centric; for the purpose of controlling the appliances, the PO collects the status and functional information from the appliances and sensors and after analyzing the information vis-à-vis the user preferences, the PO sends control commands to the appliances. If there are several users around, the POs of the users enter into a negotiation process, as to optimize the setting of the environment for all the users. In contrast, AmI is more appliance-oriented; the appliances obtain the environment information from sensors and control their own settings.

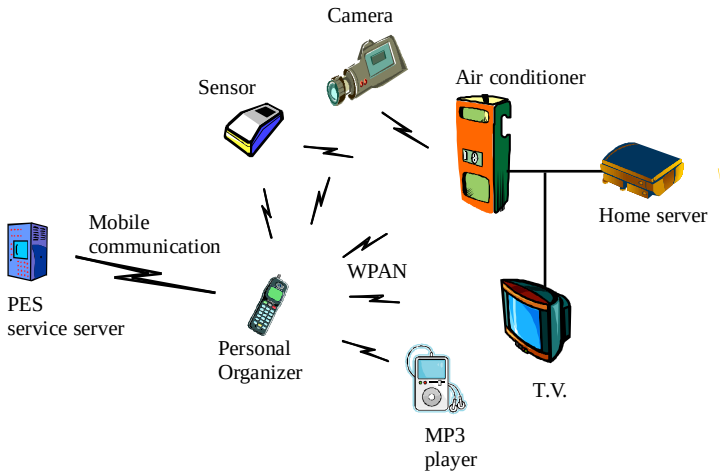

Fig. 4 The convergence of the PES, AmI, and HN technologies

In terms of connectivity, PES utilizes various short-range wireless communication technologies (e.g., WPAN, WLAN, WBAN[3]) and the Internet in supporting cost effective connectivity to the appliances around users, anywhere and anytime. In comparison, AmI constructs an ad-hoc network of sensors and the appliances within the user's environment without public network connectivity. The scope of the Home Network is limited to home.

[3] Wireless Body Area Network [10]

Because each one of these three service technologies has its own unique features, there is a merit in their integration to improve the overall functionality and the overall service quality. For example, the environment information could be acquired from the sensors in the living space and used in conjunction with the PO information to construct the customized living environment. Fig. 4 shows a scenario of the service convergence of the three technologies.

CONCLUDING REMARKS

In this paper, we surveyed the progress of location-based mobility services, and we proposed an architecture for environment mobility, which we term *Personal Environment Service (PES)*. Environment mobility, through the use of short-range mobile communication technologies such as WPAN, could support mobility services by intelligently constructing personalized living environments, customized to users' needs and desires. To realize the PES concept, appropriate set of underlying technologies should be utilized and sufficiently attractive business models should be derived. Furthermore, with the progress of the AmI and the HN technologies, careful standardization effort could result in synergy of functionality and of operation of these three concepts and in evolutionary cost-effective deployment of these technologies.

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BIOGRAPHIES

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