Pervasive Computing at Home

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Abstract
The proliferation of different computing devices such as handhelds and wall-size whiteboards, as well as Internet-based distributed information systems are creating ubiquitous computing environments that provide constant access to information regardless of the user's location. Slowly, this technology is entering the home environment. In this paper we explore the uses of pervasive computer technology at home. In particular, we describe scenarios of use of the DoMo pervasive computing architecture. Interviews with potential users were conducted to validate the scenarios and propose new ones. Based on these results we propose an extension to DoMo to support context-aware messaging. The papers ends with a discussion of the design issues that need to be considered to support pervasive computing at home.

1. Introduction

Pervasive or ubiquitous computing environments aim at providing natural interfaces to interact with a variety of devices (handhelds, laptops, electronic whiteboards, etc.) which provide almost constant access to information and processing resources to mobile users. Furthermore, this computing infrastructure should be able to sense the context in which specific situations take place and adapt to them according to its location of use, the people and objects that are around, and changes of those entities over time [Weiser 1994]. Although most research in this area has focused on supporting office environments or public places such as scientific conferences or museums, we argue that the home constitutes an environment where interactions with (and among) devices can be greatly enhanced.
We have been working on an ubiquitous computing environment named DoMo [Favela 2002]. DoMo supports opportunistic interactions with people, shared resources and services available in the vicinity of a display device (e.g., PDA, TV, cell phone, etc.). Users are registered with DoMo through an instant messaging and presence awareness server; devices announce their services through agents that act as proxies between them and potential users. We have implemented a DoMo client, named AIDA that extends the notion of the familiar instant messaging paradigm to include shared digital resources and services. In this current implementation of DoMo, shared resources, such as a family digital image or a grocery shopping list are stored in a Web server with WebDAV extensions to manage concurrent access to these documents. Services as well as documents appear as first class objects in the roster of the instant messaging application in the display device. The client displays the state of users (family members), shared documents, and available services and provides mechanisms to communicate and interact with them. As a user enters a home network with a DoMo server, all services registered in the server are uploaded to the instant messaging application and their states presented (for instance, the temperature reading of a computer-controlled air conditioning system). The user can interact with these devices, even if the AIDA client has never seen them before by means of a description of the devices’ functionality and its interface contained in an XML document that is uploaded when the agent is registered in AIDA, and parsed by it.

We consider the IM&PA paradigm to be appropriate for visualization and awareness of discovered persons and resources, as it is a paradigm that people has become very familiar with. This familiarity is due without a doubt to the overwhelming popularity of instant messaging systems, not only at work but also at home [Isaacs 2002, Grinter 2001]. It is worth noting that an important segment of these type of systems are tomorrow’s workforce; a study by the PEW Internet and American Life project shows that in the USA around 13 million teenagers use instant messaging systems, and 20% consider these systems as their primary means of communications with friends [Pew 2001]. The use of instant messaging by teenagers in Europe and Asia —where SMS and iMode on mobile phones are very popular— is undoubtedly more important.
The rest of the paper is organized as follows: we will first give a technical overview of DoMo in its current implementation, trying to show its architectural elements and functional capabilities. We will then explore how DoMo’s IM&PA paradigm could be applied to a home environment, and not only to the workplace, as originally intended. For this purpose we have carried out a series of interviews trying to get insight into the usefulness of applying these types of technologies in everyday home use. Based on the results gathered from the interviews we identify requirements for extending DoMo to support a series of common home scenarios. We will then conclude discussing some perspectives and work in progress.

2. DoMo´s Technical Overview

DoMo is an ubiquitous computing environment supporting opportunistic interactions with people, shared resources and services. A key element in DoMo is AIDA, an instant messaging and presence awareness (IM&PA) client that extends the notion of user presence to documents, devices, and other resources. As such, an AIDA client will be able not only to notify the status of other users (e.g. Online, Busy, Disconnected, Away, etc.), but also to show resources available in the vicinity (such as printers, air conditioning systems, etc.) and their status and capabilities.

By extending the notion of user presence to documents and other resources, AIDA offers new opportunities for casual encounters in a community of co-authors. For instance, when a user notices that a document has been locked, she might find this as an appropriate opportunity to send a relevant message or even join his colleague in a synchronous collaborative authoring session. This extended notion of resource presence can be applied to ad-hoc devices and services. For instance, as a user joins a private network, say in an electronic meeting room, new resources might appear as entities of his handheld AIDA client representing for example a local printer, a projector, or the air conditioning system. Through this application the user can become aware of the status of these devices (on-line, busy, etc.) or initiate interaction with them (print a file, lock a resource, increase the temperature, etc.). The interfaces through which the user can
interact with these services can be instances of the more general free-form messages exchanged between users of the instant messaging application, providing a consistent interface for users to interact with other people, documents, devices, and the services they offer.

As an example, Figure 1 shows a handheld device running an AIDA client. In Figure 1a several persons and resources are discovered (and their status is shown): those starting with “P:” are persons, documents start with “D:”, and other resources (such as devices and services) start with an “A:”, meaning that they can be reached through their agent. Figure 1b shows the options available when selecting a printer, such as number of copies to print, orientation of the paper, and the document to print (taken from the list of those discovered).

![Figure 1. A handheld device running an AIDA client to print a document](image)

The main components of DoMo´s architecture (shown in Figure 2) are:

?? A device running AIDA. This can be a handheld device (PDA, phone, smart remote control), a home appliance (TV, Internet fridge), or any other device with
input/output capabilities for user interaction. AIDA is a small footprint piece of software that can easily be loaded into the device’s memory or be embedded into a chip by the device’s manufacturer.

?? An access point. Providing mobile devices with wireless connectivity to the (wired) home network. Wireless connectivity can be based on the Bluetooth, IEEE 802.11 or HomeRF standards. The access point runs an HTTP server to handle XML/HTML communication with the mobile. In addition, it stores the Agent Directory to which agents representing services will register.

?? Agents that represent devices. These agents might run in the access point or any other processing-enabled device with connectivity to the access point. An agent implements a protocol to register into the Agent Directory, an interface to the device that acts as a wrapper to query its status and interact with it, and a Jabber client to notify the device's status to all interested users and receive XML messages through which remote users will interact with the device.

?? Devices. These are devices that offer services and are connected to the local network. Communication with the device is made through its agent. Devices define possible states, the services it offers, and the protocol used to interact with them.

?? IM&PA server. This server is used to notify the state of people and agents, and to handle the interaction between people and devices through XML messages. All communication between the handheld and the agent will go through this server. The current implementation of DoMo uses Jabber (www.jabber.org) as its IM&PA server.
3. DoMo @home

To explore the potential uses of DoMo in a home environment we first envisioned a couple of use scenarios based on our own experience. We then interviewed several potential users with a variety of profiles. We used these interviews to estimate the viability of the proposed scenarios and to determine new ones. Finally, we used these scenarios to evaluate DoMo’s current architecture and functionality and to determine how it should be extended or modified to support these scenarios.

As we have previously indicated, DoMo was designed for the workplace, mainly for collaboration and automatic discovery of shared resources. However, due to the results of the interviews previously shown, we think there may be a case for extrapolating the use of DoMo to create pervasive computing environments at homes. What follows are some proposed scenarios illustrating the practical use of such environment.

?? Scenario 1 - . Mom needs to go back to work after dinner. Her son told her in the morning that he might not have dinner at home or that he’ll arrive late that day. She leaves him a message indicating that she left food in the microwave oven for
him to dine if needed. She uses the AIDA client in her PDA to indicate that the message will be delivered to his son, upon his arrival home during that day. That is, the message will be irrelevant and will expire if the son arrives after midnight, since by then, he must have eaten elsewhere. The son arrives home late that evening and is happy to learn, after reading the message on his portable phone, that there’s some food left for him.

?? **Scenario 2** – A family member is watching TV and he has the ability of checking out the presence and current status of several entities at home through an interface similar to an instant messaging application. From a small picture-in-picture window on the TV (or through a separate dedicated channel) he will be able to watch and control the air conditioning’s temperature, the audio/video coming from the baby monitor upstairs, the status (on/off) of the lights at the backyard, etc. Figure 3 depicts a sequence diagram for the interactions that take place when, after noticing that night is falling, he decides to turn on the backyard lights. Through his remote control he opens a little window to get a list of devices and selects the backyard lights; at this point in time a software agent obtains the current status of the lights and sends it to the TV. Upon noticing that the lights are off he then presses a button to turn them on and the corresponding command is transmitted to the Jabber IM&PA server and then to the software agent that will actually turn on the lights. Finally the current status (normally on) is obtained and sent to the TV to update it onscreen. Notice that the first series of interactions, at the top of the diagram, correspond to the time when the TV is turned on and goes through the process of subscribing to the Jabber server to announce its presence and be available for interaction with other devices.
Figure 3. Sequence diagram for interactions in scenario 2

4. Exploring the use of the IM&PA paradigm at home: Interview findings

We conducted a series of interviews with 6 people of different ages and profiles (table I) to validate the possible uses of the proposed technology at home. The interviews focused on the future of technology at home, in particular the use of IM. They consisted on open-ended questions about the proposed scenarios, the future home technology, as well as follow-up probes to develop on particular points that were raised by the interviewees.
Table I. Profiles of the interviewees

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age</th>
<th>Occupation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>15</td>
<td>High school student</td>
</tr>
<tr>
<td>Female</td>
<td>33</td>
<td>Housewife and Home office worker</td>
</tr>
<tr>
<td>Female</td>
<td>13</td>
<td>Secondary school student</td>
</tr>
<tr>
<td>Female</td>
<td>10</td>
<td>Elementary school student</td>
</tr>
<tr>
<td>Male</td>
<td>26</td>
<td>Technician for the electricity company</td>
</tr>
<tr>
<td>Male</td>
<td>69</td>
<td>Retired</td>
</tr>
</tbody>
</table>

The information obtained from these interviews was analyzed and as follows: observations on the use of technology, validation of proposed scenarios and proposals for future technology at home.

**Observations on the use of technology:** One general aspect found in the interviews with the younger generations (26 and under) was the personalization of mobile phones. They program their phones to have different ringing sounds according to the person that is calling them (“…for example when it is my dad, it sounds with a scary ring sound; so I can decide if I answer or not. When it is my girlfriend it rings with wedding bells…”). They connect to their service providers through Internet to obtain the different ringing sounds, as well as to get small images to send to their friends.

Concerning the cost of mobile phone calls, there was a big concern from everybody. It was even greater from the younger generations, probably for their lack of resources. In Mexico the cost of mobile phone calls is high, although prices vary depending on the service provider, the average cost per minute of a mobile phone call is 4 Mexican pesos (around 40 cents) and for a phone message is 1 Mexican peso (10 cents). This may not seem much in a developed country, but for middle class Mexicans and specially for youngsters it is a cost to be considered. Therefore the frequency of sending messages between the younger generations is higher that the phone calls. However, they
analyze the quantity of information that they wish to communicate and/or obtain from other person, and the number of messages that they need to send in order to do that, to choose between phoning and sending messages according to the total cost. They even program their phones to beep before every minute to eliminate paying for the next one if it is not necessary (in Mexico most of the service providers charge by the minute, not by the second).

Sending messages can only be performed between mobile phones with the same service provider, constraining the communication between friends and family members to those connected to the same service. To overcome this problem young people often interchange for short periods of time their mobile phones, between close friends or relatives that have a different provider, in order to communicate with other friends and family with a lower cost.

We also observed a growing attachment to the use of mobile phones, at such extent that youngsters have them at all times even by their bedside and at the bathroom. They keep sending messages until they send good night wishes.

2) Validation of proposed scenarios:

With the proposed scenarios we asked the interviewees their point of view about the usefulness of this technology at home. We found the microwave scenario very useful for families where their members have different activities and with different schedules. In particular those where both partners work and have teenagers or young adults children. A comment from one of the interviewees was “this technology would be very good for me ...sometimes when I get back home after work, my mum left a plate of food for me in the microwave. But I arrive and check over the kitchen furniture and as I do not see any food, I cook myself some eggs and when I am going to heat the tortillas in the microwave I find the meal in there. Later or sometimes the following day I find the message that my mom left me about the meal in the microwave...”. Families with small children stay more time at home and have more control over the communication and activities that are carried out daily. Thus the comments on the use of the proposed technology, was to use it only for events under specific circumstances, such as emergencies or sudden unplanned activities. However, teenagers expressed a positive opinion to the use of this technology at home in their future lives when they grow up.
Nowadays, it is increasingly common for several family members to work, both parents and grown up children. In the same form, many professionals’ jobs require a high level of mobility and therefore there is less time for person to person communication between family members. In these kinds of scenarios, the answer to the question of how the proposed technology will affect or benefit the communication of the family was positive. On the other hand, people that spent much time at home expressed their concern about the possible damage that the proposed technology could cause to family communication.

For the second scenario, environmental control through the TV, the comments in general were positive. It was found very useful. In particular for temperature control, Internet use, door bell ringing (when people is in places were the sound does not reach), and security alerts.

3) Proposals for future technology at home: A general consensus for the future technology at home was that it should be activated by voice and remote controls. The use of remote controls not only on standard electronic devices, as we use them now, but also in computers. Facilitating the tedious activities in the use of internet, enabling people to connect, navigate and consult any information in the same way that it is done with the TV, only pressing one button, eliminating the use of the mouse and the need to open applications and introducing information in order to get where people want.

Scenarios such as to be able to keep and interact with a personal diary through personal devices such as mobile phones; to be able to control and program the home environment for a warm reception at their arrival after school/work/a day out were also manifested constantly. To be able to obtain information about security alerts and visitors ringing the door, via the TV, while they are watching it, or by light sounds when they are asleep, were some other future wishes of technology at home. In the same form, the older (26 and over) generations expressed a need for technology which will enable them to monitor and care, with the use of cameras, elderly parents or relatives, young children or somebody else, from their own homes; of course, only when the situation requires it and permits have been granted from the homeowners and people being cared for. This last scenario and others such as, to be able to leave messages (like feeding the dog) on the
home to anybody who gets there earlier, emerged as a result of the proposed scenarios and technology.

5. Extending DoMo for home use: Context-Aware Instant Messaging

Based on the scenarios described before, we identified two requirements not satisfied by our current implementation of DoMo:

?? Messages might need to be associated to devices or a particular context (place, time, etc.).

?? It might not be possible to specify the recipient of a message when it is sent. For instance one might need to send a message to the first person to arrive home.

Based on these requirements we decided to extend DoMo’s architecture to support what we refer to as context-aware communication. In particular we look to support context-aware instant messaging. This concept extends the traditional instant messaging paradigm by allowing users to specify a set of circumstances that need to apply for a message to be delivered; we refer to this as context. For instance, the sender can indicate that the message will be delivered to the specified recipient when she enters her room; or that the message will be sent to the last person to leave the house when the air conditioning is on.

For the purposes of the scenarios we have envisioned for a pervasive home computing environment we consider the following elements of context to be relevant:

?? A period of time during which the message can be sent.

?? A place or geographic location.

?? The state of devices incorporated in DoMo and represented by agents.

To implement context-aware instant messaging we need to modify our current design in its architecture and user interface.
Architecture

As is the case with most instant messaging systems, DoMo uses a client-server architecture as a basis for its implementation. The server is used to redirect the messages sent by users. In traditional IM systems messages are sent as quickly as possible. In these cases, of course, the identity of the recipient is known a-priori. This won’t work for context-aware instant messaging where the recipient’s identity will be known when a specific state is achieved.

To support the delivery of messages that are dependent on context we introduce the concept of “context agent”. This is an entity to which all context-aware messages will be sent. The context agent will monitor the environment to determine whether conditions are met for the delivery of the messages it retains for its expiration. This agent is a first class entity registered in the instant messaging server.

User Interface

We divide the discussion of the changes required to the interface of the AIDA client in two. On the one hand we need a lightweight interface for the user that composes the message to be able to easily specify the context of delivery. On the other hand, slight changes are required when the message is finally presented, for the reader to have enough context to better understand the message received.

In contrast with traditional instant messages, when a context-aware message is created the sender needs to specify the circumstances that need to be met for the message to be delivered. In the spirit of the simplicity and ease of use of instant messaging applications the additional information that the sender needs to specify should not add significant cognitive overhead to the user.

A user can specify the following information to provide adequate context for message delivery:

?? Recipient. The user can send a message to a specific user; to all users that meet the additional criteria; or only to the first user that satisfies the criteria.

?? Location. The sender specifies an area where the user needs to be for the message to be delivered. For this purpose a sensitive map is displayed for the
user, where he selects the designated area. User location is estimated by 
triangulation of at least three access points.

?? Time. The sender can specify a lower and upper bound of time for message 
delivery. He could specify either one or both. The message won’t be sent 
before the minimum date indicated and will expire without delivery after the 
maximum time.

?? State of a device. Devices define in DoMo the set of states at which they can 
be at a given time. This list of states for all registered devices is presented to 
the user if he wants to specify that the device needs to be at a given state as a 
constraint for message delivery. For instance, send the message if the lights 
are on, the printer is jammed, the camera has detected movement, etc.

From the perspective of the user that receives a context-aware message, it might 
be important to be aware of the context specified for message delivery, since this 
information might be useful for him to make sense of the message. For instance a 
message that states “please clean the room” might not be fully understood if the user is 
not aware that the message was meant for delivery at a specific location, the room in 
question in this case.

Given that the messages are not necessarily sent immediately after they are 
composed, the system should allow users to go back, consult the messages they have 
sent, and modify or delete them.

Conclusions

We have explored the potential of extending the instant messaging paradigm to 
support ubiquitous computing environments. For these purposes we have designed and 
implemented a pervasive computing environment meant to support opportunistic 
interactions with people, shared resources, and services available in the vicinity of a 
display device. In this paper we focus on the potential uses of this environment at home.
We defined a couple of scenarios of use. We conducted a series of interviews with a variety of users that gave us their perception on these scenarios and other potential uses we had not envisioned for this technology. From these interviews we also noted that this technology could be particularly useful to certain groups, in particular, families of working parents with teenage or adult children, and people caring for elderly parents living alone. The use scenarios were also used to evaluate the current implementation of DoMo. We found the need to support what we refer to as context-aware messaging, that is, the need to specify a set of circumstances that need to be satisfied for the message to be delivered. These requirements suggested important modifications to the architecture and user interface of DoMo.

We plan to modify the implementation of the DoMo architecture and the Aida client to support context-aware messaging as indicated by our proposed changes to the design.

References


