Smart Phones for the Elders:
Boosting the Intelligence of Smart Homes

William Mann, OTR, Ph.D. and Sumi Helal, Ph.D.

The International Center on Technology for Successful Aging (ICTA)
Rehabilitation Engineering Research Center on Technology for Successful Aging[*]
University of Florida, Gainesville, FL 32611, USA
(*mann@hp.ufl.edu* and *helal@cise.ufl.edu*)
http://www.icta.ufl.edu

Abstract

The ICTA center, recently established at the University of Florida, focuses on the use of wireless and pervasive technologies to enhance the quality of life and independence of elders or those aging with or into disabilities. In this article, we describe one of the research and development activities in the center that adopts the emerging smart phones technology as an effective booster of the utility of smart homes and other smart spaces. We present our vision of using smart phones as magic wands that can be used passively as remote control devices, and proactively as intelligent companions offering advises, reminders, warnings and calls for help. We also present our smart phone/home architecture and describe our efforts in early application developments.

1 Introduction

The cost of home health services for older persons with disabilities is increasing with the rapidly growing elder population. Quality of life and independence are impacted by disabilities, and our health and caregiver systems will be increasingly stressed as the numbers increase. Hence, there is a significant need today to innovate cost-effective ways to help elders maintain their independence, and at the same time, reduce caregiver burden. The impressive wireless and portable technologies we have today, and the emerging mobile computing paradigm [1] offer a unique and real opportunity for us to innovate pervasive applications and environments especially designed to support the elderly. Such environments will enable cost-effective self-care and will maintain a higher quality of life and independence for our oldest population.

Within the ICTA center, we are exploring the use of the emerging smart phone and other wireless technologies (e.g., 802.11x and Bluetooth) to create a "magic wand" that would enable older persons with disabilities to interact with, monitor, and control their surroundings and other remote resources and services. We are exploring smart phones as devices that can provide reminders to take medications or call in prescription drug refills automatically; to turn appliances off or on or check the status of locks on doors and windows; to aid in grocery shopping or help in finding other devices such as car keys, or TV remote controls. Our work is divided into the following activities: (1) determine the specific lack of usability of the current generation of smart phones and suggest design changes;

build prototypes for testing with elders; (2) develop an open middleware reference architecture that will integrate the smart phone technology with smart spaces using RF and other wireless local connectivity technologies; architecture will emphasize openness to evolving technologies and standards and will be geared towards enabling the developments of sophisticated and powerful applications; (3) develop and test several applications for the smart phones, useful for elders (applications will be prioritized based on a survey of elders with disabilities); and (4) commercialize and disseminate these applications and reference architecture.

1.1 Smart Phones

The evolution of the cell phone from an Analog handset, passing by PCS and WAP [5] (web-enabled phones), to Smart Phones [2,3] is perhaps analogous to the evolution of the apes to the human race -- they both developed sophisticated brains. By converging into a networked, general-purpose computing platform, the phone is becoming as "smart," and is defining what "mobile computers" could be for future mobile and nomadic users. Unlike WAP phones, smart phones are not limited to accessing and interacting with web contents and limited services. Smart phones are capable of accessing and fully interacting with virtually any server and information source on the network, including web services and contents.

In North America, Motorola introduced the first smart phone, the iDEN i85s [2] in March of 2001. In Japan, NTT DoCoMo introduced the *i-mod* phones almost a year ago. The full impact of the smart phone technology on individuals and societies is yet to be realized.

A major enabler for smart phones is recent effort by Sun Microsystems, that aims at "standardizing" the phone platform. The Java 2 Platform, Micro Edition [4], or J2ME allows small devices such as cell phones or PDAs to use the Java programming language and to engage, as clients, in networked client/server interactions. Several vendors are converging today to the J2ME platform.

In this paper we describe our approach and open architecture and give a brief summary of applications that we have developed or currently developing in the ICTA center for elders with disabilities.

Figure 1. Smart Phone a Companion and a Magic Wand

2   Our Approach

We strongly believe that smart phones will play a pivotal role in creating radically effective solutions for successful aging. Smart phones are a technology that enhances the utility and effectiveness of smart environments. Simply put a smart space needs a smart device that can represent and enable the elder user to interact with the space. Without such complimentary intelligence, the effects of the smart space are limited (and perhaps burdened) by a one way, non-adaptive flow of intelligence. We explore the use of the smart phone as both a passive and active device that can support the elderly in almost all aspects of their daily lives. As a passive device, the smart phone is used as a command and control device or a "magic wand" serving the elderly and enabling them to gain control over their lives and their independence. As an active device, the smart phone is used as an intelligent agent or a "companion" caring for and guiding the elderly, and in general augmenting their fading sensory and motor abilities. Figure 1 depicts several use scenarios of the smart phone, ranging from a device to turn light on/off in a remote room; to remotely check on the kitchen stove; to see and verify identity of visitors at the front door; to lock/unlock front door; to call in a nurse or a handy person, to call in groceries or catered food; or to find out where the TV remote or car keys are hidden. The smart phone can also be used to scan prescription drug bottles and read their instructions; remind the elder to take his/her medications at the right times of the day or night; and even call in a refill automatically and arrange for home delivery.

Even though we are excited and committed to using the smart phone technology for elder care, we realize that several pre-requisites must be met before the technology is practical and useful for this purpose. First, the smart phone in its current form and shape is not suitable for elders. We are currently working on usability studies to define design requirements of a smart phone that would be most suitable to this group of users. Second, we realize that a software infrastructure is needed to enable a wide range of thought-of and un-thought-of applications, including the above-mentioned scenarios.

2.1   Designing A Smart Phone for the Seniors

The current design of the smart phone is optimized for young and highly mobile people, which is opposite from the elder group we are concerned about here. Hence, there is room for design changes that would render the phone more usable by the elders. Figure 2 depicts the first commercially available smart phone in the North American market, the Motorola i85s phone. We will be working with Motorola to redesign the phone by taking into considerations several ergonomic and accessibility aspects as shown in Figure 2. The keypad is especially important to redesign to allow visually impaired elders to press keys easily and reliably. The vertical and

horizontal spacing between keys and the font size of the key labels will be studied. . Additional ways to augment the keypad using the display will be researched. The display size will also be examined and guidelines for application interface design will be developed. Such guidelines will streamline application developers' efforts and will ensure usable application GUIs on the smart phone. We may also conclude that the display size and the image resolution in pixels may have to be enlarged. Through surveys and interviews with the elderly, we will examine the acceptability and effectiveness of the new design in terms of its user interface.

Figure 2. Smart Phone Interface Extensions for the Elderly

2.2 An Integrated Smart Phone/Home Environment

A major challenge in this project is achieving an open integration of several emerging technologies without committing or locking any aspect of our architecture to the particularities of any of the technologies. We are currently facing this challenge in designing our architecture around the following set of technologies:

- Smart phones with mobile-IP and Java 2 Platform, Micro Edition programming language capability
- Broadband DSL or cable modem Internet service to the home
- High speed, wire-line home area network
- Wireless local connectivity: Wi Fi or Bluetooth
- X10 computer-based home control for home appliance control
- Wire-line, networked micro-controllers for custom appliance control
- RF-based micro-controllers as basis for small footprint sensor network.

A target intelligent home environment that would result from such integration is shown in Figure 3. Components of this environment are:

- A Java-enabled smart phone with a fixed Internet address (routable IP), dual RF interfaces, and a code reader interface (e.g. barcode reader). The first RF interface is the cellular interface, which is controlled by a commercial carrier, and incurs connection charges for voice minutes or data packets. The second RF interface is either Wi Fi or Bluetooth, which provides local connections between the phone and an appropriate near-by wireless access point.

- An *always-on* home networked server, with a routable IP. The server connects to the Internet through a broadband Internet service provider (e.g., cable modem or DSL). The home server also connects to a high-speed, home wire-line network (e.g. fast Ethernet). The home server hosts our middleware and application software.

- An X10 controller connected to the home server. The controller connects through the home power-line network to a number of X10 module interfaces. Various home appliances and devices can be attached to the module interfaces. X10 software that coordinates X10 controller/module interactions is part of the middleware hosted on the home server. The reliability of the X10 technology is questionable, and other power-line based alternatives are being investigated.

- A home wireless network, which could be based on Wi-Fi or Bluetooth technologies. The network consists of a number of wireless access points covering parts or all of the house floors. The access points are connected to the high-speed home wire-line network, and allow connections from devices with compatible RF interfaces (e.g., the dual RF smart phone, or other devices) to the home wire-line network.
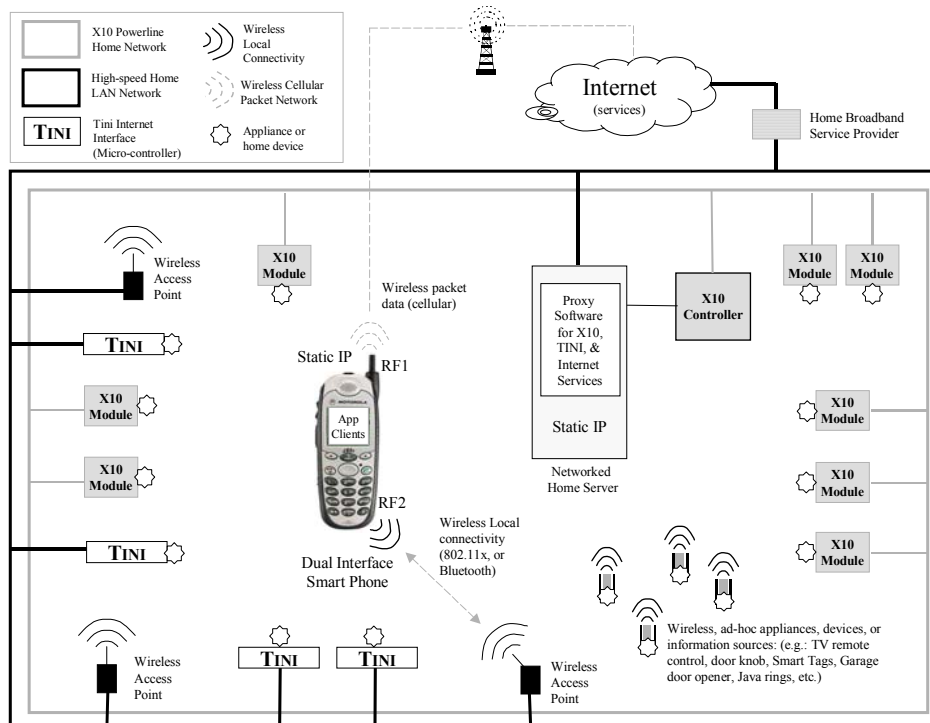
Figure 3. System Connectivity: A Smart Phone in an Intelligent Environment

- Micro-controllers with wire-line network interfaces. Such controllers will attach to devices and appliances that require special control. The micro-controller attaches to the high-speed home wire-line network, which allows for over the network interactions with the controller and the device. Examples of such micro-controllers include the Dallas Semiconductor Tiny Internet Interface (TINI). The TINI controller comes with a built-in micro HTTP server, which aids significantly in accessing and interacting with the device through a standard HTTP client interface.

- Micro-controllers with wireless network interfaces. These are micro-controllers that connect objects (including ah-hoc objects such as TV remote) to wire-line microcontrollers, and eventually the home network via a wireless local connectivity (802.11x or Bluetooth). There are currently several emerging RF/microcontroller chips with power programmability tools. We are looking at the feasibility of using this technology.

The intelligent environment depicted in Figure 3 should ideally allow the following connectivity paths for the various future applications:

- Using its cellular RF interface, a smart phone should be able to initiate or receive a voice phone call through the nearest tower (base station). It can also send or receive data packets through the base station, which is connected through a gateway to the Internet. A smart phone can therefore communicate with any routable IP on the Internet, including the home server through the broadband Internet service provider.

- Using its wireless local RF interface, a smart phone can connect to the home network via a near-by access point. The smart phone can send or receive data packets to the home server or route packets through the home network router to external Internet destinations.

- A smart phone can interact, through the home server, with appliances, objects or devices with X10 control support. The X10 power-line network is connected to the home server through the X10 controller, which is manipulated through a software module on the home server. By interacting with this software module, the smart phone can control and interact with any X10 module on the network.

- A smart phone can interact with micro-controllers wired into the home network through any of its two RF interfaces. Either will connect to the home network, to which the micro-controllers are also connected.

- A smart phone can interact with objects connected to wireless micro-controllers through their wireless-line microcontroller matched pair.

- Finally, remote Internet services, the home server, wire-line and wireless micro-controllers can each communicate with the phone by initiating connections through either one of its two RF interfaces.

3 The Smart Phone/Home Reference Architecture

The home server plays a central role in enabling the integration of the infrastructure components and technologies. It is also responsible for creating various connectivity paths in the home environment. Details of the proposed architecture are outlined in Figure 4. The architecture is event driven, where

actions are fired when certain events occur and certain conditions are met. Event/Condition/Action rules are specified and stored in an ECA rules database. On occurrence of events, an ECA engine evaluates rules from the database and fires the appropriate actions. The ECA rules database and the ECA engine, collectively, make up the centerpiece of the home server architecture. One example of such events is the arrival of an Internet service request to the phone. This could be a request by a caregiver to collect the last set of medical measurements stored in the phone. Another example event could be an awareness cue posted by the front door micro-controller indicating the doorbell is being rung. User commands issued from the smart phone will also be treated as events. The appropriate rules will dispatch a user command to the appropriate entity in the home environment by firing the appropriate action. A command to turn off the living room lights will generate actions that are function calls to the X10 software that manipulate the X10 light modules of the living room.
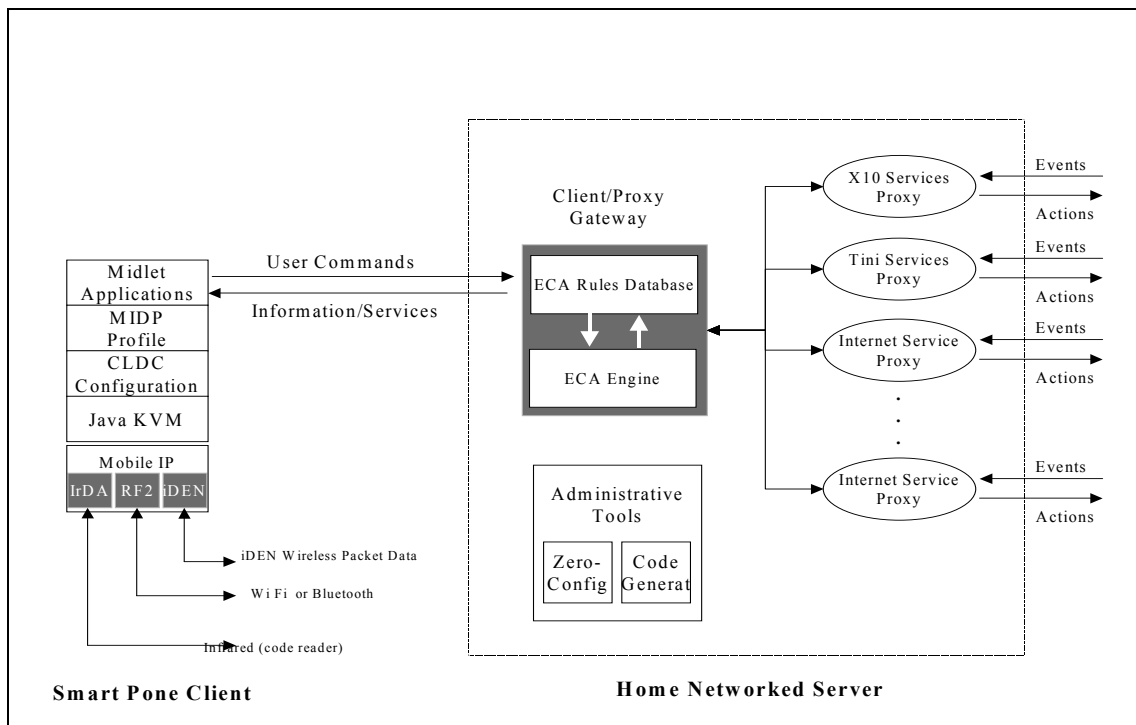

Figure 4. Smart Phone/Home Reference Architecture

In an intelligent environment, events may have different representations and consumption semantics. Furthermore, associated actions specified in ECA rules will need to be mapped to implementations unknown to the ECA engine. This complicates the development of an event-based architecture. Our approach to achieving a uniform abstraction of events and actions in this environment is to use a *proxy* middleware between the smart phone and the different entities in the intelligent environment. We will develop proxies for each class of event sources in the environment. This will include an X10 proxy, micro-controller proxies (e.g. a TINI proxy), and Internet application proxies. Specialized proxies will understand both the low level details of events and actions as well as the corresponding ECA abstractions, and will provide the correct mapping between the two. Also, all proxies will conform to a unified representation of events, conditions and actions. Collectively, the ECA engine and the associated proxies will provide the glue necessary for the integration, and the reactivity necessary for the coordination and application development.

In addition to developing the gateway and the proxies, we will develop sophisticated administrative tools that enable the rapid creation and cloning of intelligent environments, and that minimize the overhead associated with establishing and maintaining environment configuration. Adding or removing objects and devices to the environment should not be a daunting operation in terms of proxy coding or system configuration changes that must be made. In other words, we do not have to require an engineer's help or "recompile" the smart space just because an object is added or removed. We are planning on developing administrative tools that support code generation of parts of the proxies and that enable a plug-and-play style of environment change and evolution. We are currently investigating service discovery and delivery protocols to be used for this purpose. We believe the administrative tools will provide a great support and protection against technologies and devices that are ever changing and evolving.

3.1 Application Development

It would be risky to defer our efforts in application development until we fully develop our reference architecture. Therefore, we are currently engaged in two efforts in parallel to our architecture development. The first is to determine an initial set of smart phone applications, prioritized based on early surveys that will be conducted with a study group of elders. A tentative initial set of applications is shown in Table 1 below. A finalized initial set will be carefully determined before the survey is conducted.

Table 1: Example Applications

Location Tracker: elder finds her whereabouts
Security Alert: alerting the elder to security breaches
Unlocking Device: lock/unlock doors and windows
Intercom: elder talks to person at the door
Emergency Alert: phone alerts care giver
Reverse Locator: others find elder's whereabouts
Mapmaker: elder finds directions to destinations
Pager for TV Remote: phone pages TV remote
Switch functions: turn on/off light, stereo, etc.
Alert/Alarm: phone alarms elder to take medications
Weather Info: elder queries phone for weather conditions
Mail Notification: phone notifies elder of mail arrival
Grocery shopping assistant: phone as shopping assistant
Dictation: phone takes and organize notes from elder
On demand service ordering: elder shops (eg. order a pizza)
Remote monitoring: phone shows images of remote places
Bookkeeping of health measurements: taking blood pressure

The second effort is to prototype some of the applications in our list. We have already prototyped several applications and have gained an early understanding of the complexity of building suitable user interfaces, and the difficulty of achieving acceptability by the elder. Figure 5 below depicts an application scenario where the elder uses her phone as a reminder tool to take her medicine. The phone provides reminders and maintains inventory of the medicine. Before the medicine runs out, the phone calls in a refill to the pharmacy. A home delivery is arranged and a man shows up at the front door. The elder is notified on her phone as the elder rings the bell. Elder sees who is at the door (slow video rendering on the phone, currently), and if necessary, she will turn on the door light to see better – all done through her phone. Realizing it is the pharmacy man, the elder uses the phone to unlock the door and let the delivery man in.
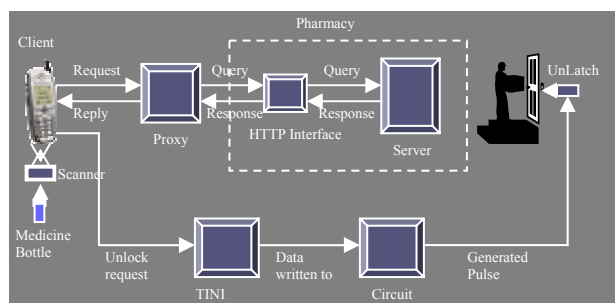

Figure 5. Sample Application Scenario

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