Integrated Home Network
CSE 537S – Mobile Computing

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Abstract
The purpose of this paper is to propose an architecture that would be used to integrate various existing and emerging technologies with the result of creating an Integrated Home Network (IHN). The concept of an integrated home network is a logical extension of the personal area networks already deployed with the Bluetooth and related technologies. The concept of the IHN is to create a single point to coordinate many of the devices making control more cohesive. Thus, it is desirable to have a single device such as a PDA serve as a mobile hub to control, manage and organize much of the daily operations for a home.

Suppose you wanted to modify prescheduled heating/cooling assignments for a programmable unit. It would be convenient to make the desired adjustments to your PDA at any point and have the updates uploaded. Suppose that you hear about a television program that you would like to view. It would be convenient to schedule the program in your PDA and have the information uploaded to a home entertainment center to schedule the program for viewing or recording. Another example would be to use emerging technologies such as the smart refrigerators to track items that need to be replaced and upload the list in your PDA. This would allow access to the typical grocery items needed when at the store.

Design Considerations
It is possible to integrate a myriad of wired and wireless devices into a single cohesive home network using existing technologies such as Bluetooth in combination with some possible middleware applications. Use of Bluetooth lends itself well to a possible solution for several reasons. Most wireless devices already operate in the designated frequency band associated with Bluetooth. The standard is well defined and already implemented in many devices. And the low power requirement of Bluetooth lends itself to the design considerations without resulting in any significant design limitations.

Technical Issues
The technical issues focus upon the integration of wired devices as well as on the integration of legacy wireless devices in addition to newer devices that inherently implement Bluetooth. In order to consolidate these systems into a cohesive IHN, it will be necessary to have middleware and/or hardware to support such wired and legacy systems.

Fortunately, some of these challenges have already been addressed by several manufacturers that build “universal” home remote controls, where by a single remote can control all aspects of say a home theatre system. One company in particular, Phillips, has created a home remote called “Pronto” which integrates several home devices into a single remote with a LCD display panel. This device uses Bluetooth, WiFi, and IR protocols to interface these various devices. Range extenders using WiFi with IR outputs can be added throughout the house to ensure communicated between all devices. However, there are still limitations to this system which fall short of meeting the requirements of this proposal, the largest of which is being able to control these devices while away from the home.

Proposed Hardware Implementation
One of the keys to solving the hardware technical problem as well as supporting the marketability of this concept is to be able to design the software such that it can be supported on a variety of hardware platforms (PDAs, Cell phones, iPhone, etc) which support the hardware requirements (WiFi, IR, etc). The other key element to the proposal is to modify the architecture model seen in the Phillip’s home remote such that there is not only a mobile primary control device such as a PDA, but also a base station which always resides in the home. This modification allows the primary control device to directly control devices while in the home. It also allows the device to communicate with the base station via the internet and maintain full functionality while at a remote location. In this case the base station may be a dedicated piece of hardware with an IP address and a Bluetooth/WiFi capability. However, another more likely and cost effective solution would be a PC running the base station software.

An additional modification to the aforementioned Phillip’s architecture is to the range extenders. Rather than dedicated extenders for various signal types (i.e. a separate extender for IR, a separate extender for RF, etc), a single extender box can simply be a powered device with several USB ports running a small software application for translating the incoming commands via Bluetooth into the appropriate signal type for communicating to the desired device. To provide the appropriate output signals, low cost commercial off the shelf (COTS) USB adapters can be added to the range extender. This concept allows the range extenders to be tailored to each location based on the current needs. If the needs for a given location change,
the USB adapters can simply be added or reallocated to different areas of the house. This is a much more flexible and cost effective approach. USB adapters can provide the added advantage of allowing older hardware, which may not natively support the various protocols and signal types, to be used for both the primary control unit and the base station PC.

**Proposed Software Implementation**

Maximum flexibility will be obtained in interfacing with a wide variety of wireless devices if the underlying software builds upon the implementation provided via the specifications for the Bluetooth protocol. Thus, it significantly simplifies the introduction of a number of new elements as part of the integrated home network since many hardware/software products support the Bluetooth specifications. Legacy systems can also be implemented via the use of the previously mentioned hardware that acts as a medium to serve as an interface between the legacy system and the IHN.

From a software perspective, legacy components integrated into the IHN will require not only the additional hardware but also a native software component associated with the hardware to translate the messages into an appropriate interface for the legacy device. Since many of these devices have similar but often unique IR or RF protocols, the corresponding software must be generated in a device by device basis. As such, the discussion of software related to the integration of non-Bluetooth devices will be limited to the acknowledgement that they may be numerous, widely variant, and have little standardization in interfaces. However, while their actual interface may be varied, the same hardware may support a host of devices and may be adaptable for various devices by the software load resident on the device. For example, an IR interface device may support numerous IR devices as long as the software load is appropriate for the type of device it is interfacing.

From the perspective of the software needed for implementation of the IHN proposal of this paper, there are two areas that need to be considered. The first is the software that would reside onboard the user PDA to provide the capabilities described in the abstract and later in the User Interface section of this paper. The second area is the software that resides on the network HUB (PC base station) of the IHN. The local transmitter/receivers that reside locally in each of the rooms of the home that contain the IHN devices are simply “dumb terminals” and serve as an interface to the PC. As such, they require only software to support operation of the hardware functionality.

Before describing the aspects of the two software components mentioned, some key software design component issues will be described that are fundamental to the software that resides on both the PDA type and PC base station devices. First, since any two devices that may be integrated into an IHN may have significantly different interfaces, a method must exist to support a large variety of devices while constraining the requirements of the IHN components (i.e. the PDA and PC). This will be accomplished through the use of software plug-ins. In the same way that software drivers are installed to support various hardware devices on a PC, software plug-ins will be installed to support the devices that are added to the IHN. Doing so prevents installation of software components to support a huge number of devices and limits installation to those that are specific to the associated IHN.

The software onboard both the PDA interface and the PC base station share some common software capabilities. Each of the components carry the software plug-ins needed to communicate with the various elements serving as a node in the IHN. Inherent to the software is both the capability to issue commands and process responses associated with a given device on the network but also the necessary GUI interface to allow the user to interact with the device. Additionally, both components will have the ability upon discovery of a new device to attach to a remote service provider, query the service for the appropriate plug-in, and download the plug-in as appropriate.

Either of the components may function independently via their onboard software loads. Additionally, these components may operate cohesively using the Bluetooth protocol to synchronize IHN coordination in the same way that current PDAs use simple docking equipment. Thus, when modifications or event triggers for the IHN are modified via the PDA they are updated by the PC base station when the PDA is connected locally. Conversely, any modifications made to the PC base station either locally or remotely via the internet are updated in the PDA in a similar manner. Synchronization of event modifications can be managed simply via a time stamp associated with an event modification. Time stamps can then be compared for event conflict resolution between the base station PC and the PDA. This software design also
serves as a mechanism for acting as an auto-backup in that if either the base station PC or PDA suffers from a system failure, the current state of the IHN is easily restorable from the other component.

**Primary Control Unit Platforms (PCUPs)**
The requirements for the PCUP (e.g., the PDA devices) are such that many of today’s wireless communication devices are feasible hardware solutions. Each device must have a color LCD display with both IR and RF transmitters and receivers. Additionally, the devices should natively support WiFi and Bluetooth protocols. Since this protocol is designed with wireless devices in mind which typically have limited resources in the terms of both memory and hard disk size, the software footprint and memory usage of the protocol will be designed around these considerations. However, the PCUP device must have a sufficient memory to store the core software program and any device plug-ins needed for a given installation.

**User Interface**
A Graphical User Interface (GUI) will be used to control the IHN software and provide interfaces to each device registered with the IHN. For consistency, the GUI controls and interfaces will be represented the same on both the PDA and the PC base station residing in the home. Thus, a focus on simplicity will be a key design criterion in the GUI creation since the PCUP will have a far more limited screen space with which to work. Consistency among control interfaces for differing devices will also be a primary design consideration. This means that functionalities that are generally common among many devices will use the same symbology and control interfaces. This will include typical controls such as volume, power on/off, etc. Additionally, user inputs will primarily be driven by an arrow keypad surrounding an “OK” button on the PCUP as this has become a standard in the wireless device hardware. This input scheme can be mirrored on any standard PC keyboard using the arrow and enter keys.

**Marketability**
Wireless devices have permeated modern society in recent years. The market has responded to consumer demand for access to data, music, the internet, and communication anywhere at any time using only a single device. In seems a natural progression for consumers to want the ability to interact with their home in the same manner using the same device. Currently there are companies beginning to produce solutions for in-home single control panels that interact with many of a home’s devices. Thus, there clearly exists a market for integrated home control. However, today’s technologies do not meet the consumer drive for all functionality integrated on a single piece of hardware that can be taken anywhere and maintain the same level of functionality. The IHN will give consumers that ability and in a more affordable and flexible solution that is consistent with today’s market trend toward mobility.

In addition to the fact that there exists a consumer demand for the proposed IHN, the potential return on investment is extremely high for several reasons. First, the proposal of the IHN does not require the development of any new hardware technologies. All functionality proposed in the IHN concept are currently available and supported by hardware currently available in industry and in most cases from commercial off the shelf (COTS) components. Not only are these components available, the return on investments for basic hardware integrated into software/hardware packages is very high as they are reflected in high markup rates. Additionally, as each IHN will inevitably require hardware deployment within multiple room for a given home, the hardware demand will be sufficient to quickly recover the cost of research and development of the product without become cost prohibitive. Finally, the last two decades have seen a paradigm shift in the primary developmental cost of new products. Hardware acquisition and development cost now tend to pale in comparison to engineering and software development costs.

Second, this proposal not only benefits from the hardware aspects described but also benefit in software development. The required software implementation described in the software section illustrates how the software components exhibit great commonality and have extensive reusability. Building upon well established and documented standards leads to rapid development and adds to cost savings in the software development process.

Finally, the concept is simple, the functionality desirable, and the deployment cost is not prohibitive availing the product to a large target audience. As such, it is conceivable that the deployment of the proposed technology could result in such wide spread usage that “IHN” could become a commonly
understood acronym. The potential is so great, household device manufacturers may actually become a source of revenue in order to claim their devices as “IHN supported” in the same way that devices today bolster Bluetooth or WiFi enabled.

Conclusion
This paper has proposed a solution to allow both local and remote wireless integrated control of any in-home devices supporting WiFi, Bluetooth, RF, or IR communication protocols from a single control device. The design approach uses a COTS hardware solution to provide a flexible and cost effective solution for establishing the IHN network. The software employs known methodologies in the areas of protocols, keeping software synced between the PCUP and base station device using docking stations, and loading the control structure for devices via plug-ins. Using proven technologies in an innovative way that meets emerging consumer demands makes this proposal both technically feasible and financially sound.