Pin&Play: Networking Objects through Pins

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Abstract. We introduce a new concept of networking objects in everyday environments. The basic idea is to build on the familiar use of surfaces such as walls and boards for attachment of mundane objects such as light controls, pictures, and notes. Hence our networking concept entails augmentation of such surfaces with conductive material to enable them as communication medium. It further incorporates the use of simple pushpin-connectors through which objects can be attached to network-enabled surfaces. Thereby users are provided with a highly familiar mechanism for adding objects ad hoc to the network, hence its name Pin&Play. This paper describes the architecture and principles of Pin&Play, as well as the design and implementation of a smart notice-board as proof of concept.

1 Introduction

Large surfaces such as walls and notice boards are one of the most common supporting structures for the display and exchange of information. They support the meaningful arrangement of many kinds of objects in everyday environments, for example clocks, calendars, lights, controls, pictures, notes, and posters. Many objects may be attached long-term on a surface while others may be replaced or relocated very frequently. Obviously, the easier an object can be attached to a surface, the more control users have over their environment. In this paper we propose a new type of network that seeks to build on the role of surfaces in everyday environments, and that aspires to particular ease of user control. We call our concept Pin&Play as it foresees the ad hoc connection of objects by literally pinning them to a networked surface.

Technologically, Pin&Play rests on two fundamental components. The first one is the augmentation of potentially large surfaces with embedded conductive material to enable them as two-dimensional network media. The robust augmentation of surfaces for networking is a fundamental design challenge. However Pin&Play surfaces are in principle simple in their composition, thus supporting a vision of deployment at large scale and relatively low cost. The second defining component is the use of pushpin-like connectors, for socket-less attachment of objects to a Pin&Play surface. The use of such connectors enables free placement on a surface and thereby a large degree of flexibility for physical arrangement of networked nodes. Moreover, the use of pushpin-like connectors provides users with a most familiar mechanism for attachment of objects.

The technology design of Pin&Play is driven by the general aim to facilitate everyday environments with computing in ways that do not break with accustomed uses but instead exploit existing affordances. This relates to ideas of calm computing as expressed by Weiser and Brown [8] and to other human-centered interpretations of the ubiquitous computing vision as, for example pursued in Europe's research initiative The Disappearing Computer [2]. However, our work has also received some inspiration from other technology proposals, in particular from the Networked Surface [4] and Pushpin Computing [3]. The relationship of Pin&Play to these works will be further explored below.

The purpose of Pin&Play is to network objects in everyday environments, and it is important to view the technology in relation to networking trends in ubiquitous computing. In contrast to networks for conventional distributed computer systems, networks for ubiquitous computing are typically less concerned with bandwidth optimization and widest possible reach, and instead aimed at high density and integration of large numbers of nodes per volume [9]. Another important trend is the integration into everyday environments and especially homes. Work in this direction includes home network provision of consumer electronics (e.g. IEEE 1394 "Firewire"), the use of existing infrastructure (e.g. powerline and phoneline), and the deployment of wireless solutions (e.g. 802.11 and Bluetooth). Pin&Play is not challenging any of these developments but proposed as a complementary technology, addressing a design space between wired and wireless technologies. It is distinguished by enabling particularly dense networks of surface-attached objects, by exploitation of powerful affordances in physical spaces, and by the simplicity of use and control.

The aim of this paper is to provide an introduction to Pin&Play outlining the key ideas, and to report the design and implementation of a smart notice-board that we have built as proof of concept.

2 Architecture and Properties of Pin&Play

Pin&Play is based on the vision that walls and other common surfaces can be used as ad hoc network and communication bus for objects that become attached to them. This is a vision that requires a novel network composition, and that is concerned with qualities not typically considered in networking, e.g. facilitation of everyday environment and exploitation of design affordances for ease of use.

2.1 Pin&Play Architecture

Pin&Play is based on the following components:

- Surface: physical medium for both data and power
- Connector: physical device for attachment of objects to the medium
- Objects: network nodes powered and connected through the Surface
- Network: network control and communication protocols

Surface. The purpose of the Pin&Play physical network medium is to provide both network connectivity and power to attached objects. It is based on conductive sheets rather than wires as the objective is to facilitate entire surfaces as two-dimensional network. As solid sheets would leave holes when pushpin connectors are inserted and later removed, fiber sheets are used instead. Pin&Play Surfaces are composed of multiple layers of such sheets embedded in common surfaces. An anticipated challenge with the use of sheets rather than wires is that resistance and capacitance can be expected to increase faster over short distance, as surfaces get larger. However, a range of conductive materials are available that are optimized for low resistance. In general, the Surface design is aimed at simplicity and low-cost, for example avoiding subdivision into tiles, to hold up our vision of practical deployment in everyday environments. Deployment of the surface material could for instance be envisioned in the form of smart lining under standard wall paper in the home, to enable entire walls as shared medium for objects that are attached to them.

Connectors. The design of Pin&Play connectors is aimed to support two very different functionalities in a single mechanism. First, they obviously have to support physical connection of Pin&Play network nodes to the Surfaces (they would be the plugs if the network were not socket-less). Secondly, they should support attachment of objects based on existing and familiar practices. The Connector design is therefore based on pushpins that can be stuck into Surfaces, and that can be removed as easily, thus employing a truly ubiquitous device that is commonplace in home and work environments. The Connector design is further aimed at flexible augmentation of objects and hence conceived as adapter rather than built-in physical interface.

Pin&Play Objects. The very idea of Pin&Play is to provide networking to objects that are commonly attached to surfaces, rather than too conventional computing devices. In general, we consider two different types of object. First, we envision that any kind of object that people would attach to vertical surfaces can be "upgraded" to a networked object while also retaining its original appearance, purpose and use. This would apply for example for picture frames, artwork, wall calendars, clocks, light controls, and so on. Secondly, we envision objects that succeed today's mundane and ubiquitous connectors and fasteners, for example "Smart Pushpins" that can be used to attach notes to boards but that in addition provide new functionality on the basis of being digital and networked. Obviously, both types of objects require unobtrusive embedding of computation and network interface. In this context it has to be noted that Pin&Play Objects do not require their own power supply unless they are required to be "on" in detached mode.

Pin&Play Network. Objects become powered up when they are attached to a Surface. It is the task of the network to discover newly attached objects and to maintain network state. The network further has to provide the communication protocols for the connected nodes. A primary optimization target for the network is to support large-scale surfaces, high density of nodes, and ad hoc integration of previously unknown objects, while bandwidth is of lesser concern.

2.2 Properties of the Pin&Play Technology

The design of Pin&Play differs substantially from other conventional computer networks and other networks proposed specifically for ubiquitous computing.

Networking Properties. Pin&Play addresses a design space between wired and wireless technologies. On an imaginary scale of ubiquity of network access, it goes beyond one-dimensional wired structures in providing network access across 2D surfaces, while of course not going as far as offering connection throughout 3D volumes. However, we consider it likely that overall higher density of nodes per room can be achieved if the enclosing walls were networked, in comparison to the state of the art in wireless technologies. A main advantage of Pin&Play over wireless technologies is that it provides power to connected objects, and thus supports the integration of objects that have no batteries or other power supply. The approach is very similar to that of a PDA-cradle or a laptop docking station, but with minimal constraints concerning where and how to connect the object, and with more direct interconnection possibilities.

Use-Related Properties. We already stressed that the Pin&Play concept is firmly built on common structures. It addresses important user values such as familiarity of the concepts used, better observability of network configuration, and straightforward control in the sense of minimal-effort attachment and detachment of objects. Pushpin-like connectors provide a strong affordance, and the user act of connecting an object to the network becomes embedded in the act of attaching it to the wall or other surface. Another important property is the free placement of objects on a Pin&Play Surface. People use surfaces for meaningful spatial arrangement of objects and therefore it is valuable that surface augmentation does not constrain such use.

Deployment Vision. Pin&Play is at this stage of our investigation a highly speculative technology, however its design is clearly targeted at practical deployment in everyday environments. The components underlying Pin&Play, in particular the layered conductive fiber sheets and the pushpin-like connectors, require careful design but do not involve sophisticated or expensive technology. If a satisfactory design is achieved, production at low-cost would certainly be realistic.

2.3 Related work

There is a broad spectrum of work that in a wider sense is related to ours, for instance research into ubiquitous computing networks, on interactions in smart environments, and also on how people interact with physical space. For the sake of space and in the interest of focus we will here only discuss other work that is particularly close to ours.

Lifton and Paradiso have proposed Pushpin Computing [3]. They use a similar infrastructure with pushpins and layered conductive sheets, where the pushpins communicate through capacitive coupling or infrared and use the direct contact to the conductive layers in the board only to obtain ground and power. The network is not based on a bus topology like in our approach – their pushpins communicate only with neighbouring pushpins in a close (~10 centimeters) range. Pushpins feature in this concept as explicit computational elements to create a new type of computing architecture. Whereas Pushpin Computing is centered around pushpin-like devices as uniform computational elements, our approach is more modular in separating networked objects from the connector technology, hence creating a broader design space. Pushpin Computing is focused on novel computing architecture and not concerned with facilitation of everyday objects and environments, which makes their approach very different from Pin&Play in both philosophy and envisioned use.

The Networked investigated at Cambridge University [4] is very similar to Pin&Play in that it builds on surfaces in everyday environments, but with focus on horizontal surfaces such as desks and tables. In contrast to Pin&Play the created network is primarily aimed at connection of higher-end computational devices that are placed on top of it, such as handheld and mobile computers. Instead of using layers, the Networked Surface is composed of cleverly placed tiles, such that there is a connection to power, ground, and communication channels at all times. Objects can be connected to the surface through circular pads designed to map with connection points onto the tiles. These pads are considerably larger than Pin&Play connectors and not well usable with very small objects. Interesting though is that the Networked Surface also provides information about position and orientation of objects, to be derived from the internal surface structure. A drawback of this structure is the complexity: the network has to manage a large number of tiles in the surface and to negotiate connection points with object adaptors.

Wrensch et al. describe the rototack, a pushpin-like device with embedded computation and actuator [10]. The Rototack exhibits Pin&Play behaviour in that it begins to “play”, i.e. execute pre-programmed actions, when it is pinned to a common surface, in this case a corkboard. The project though is not concerned with networking or power provision through a surface.

3 Proof of Concept: a Pin&Play Noticeboard

To validate the Pin&Play concept we have build smart notice-board that provides networking to attached pins which are augmented to support notification. This notice-board is based on a common corkboard and drawing pins one can find in most home and office environments. The Pin&Play notice-board demonstrates new functionality added to an everyday artifact however our focus was to implement our technology concept rather than to design a particular application. It is also important to understand that the Pin&Play concept is by no means tied to pushpin and notice-board applications.

3.1 Surface: Augmenting a Corkboard as Pin&Play Medium

The physical augmentation of the corkboard to a network bus was achieved by adding two conductive layers, using the cork as insulator (see Figure 1). The conductive fiber sheets, which are traditionally manufactured for shielding applications, are not only straightforward to apply; they also leave no holes once the pins have been removed which ensures it can be used longer than solid conductive sheets. They do have a higher restistivity than plain network wires with a surface resistance of maximally 0.09 Ohms, or 0.05 Ohms on average per square, which will affect scaling up the board size. The fabric is usually silver (Ag) or nickel-copper (Ni-Cu) plated nylon and has a typical thickness of 0.1 millimeters (0.005 inches) [5].

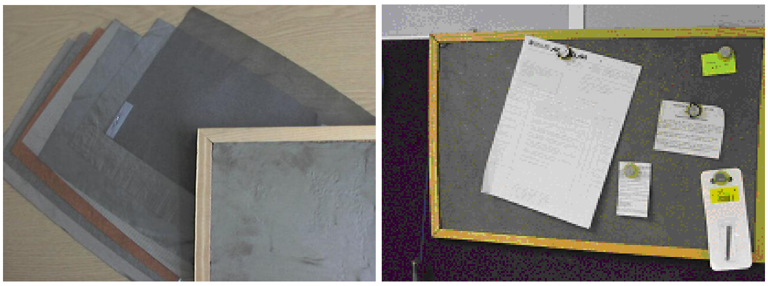

Fig. 1. Left: the Pin&Play enabled notice board, with various woven samples of conductive fabric in the background. Right: the notice board being used.

We opted for assigning the ground layer in front and the data layer in the back of the corkboard, because the data layer is more protected, while the ground layer could stay on top of the board, requiring no additional covering. Furthermore, when working with very large surfaces, it might be necessary to tile several boards next to each other, all using the same ground layer. In that case a common ground layer in front would be desirable for both mechanical and aesthetical reasons.

3.2 Connectors: Design options

Our current prototype has two isolated pins to get into the front and back layer of the corkboard, much like that of the Pushpin Computing approach. This connector design, with the larger pin partly covered with a transparent isolator (Figure 2, left) has the potential disadvantage of being fixed in orientation once it has been plugged in. It is also somewhat vulnerable to short-circuits since the tips of both pins are more accessible. Obviously, the two-pin design alienates the connector somewhat from common pins. While the devices are still very easy to attach and detach, we realized that two pins make it comparatively more difficult to push the device into place. As an alternative, we consider a single-pin design with a prototype implementation shown in Figure 2 on the right. This prototype uses an industrial stainless steel nozzle containing a

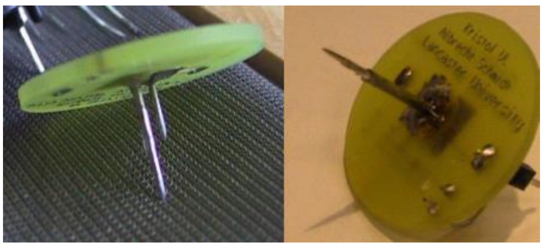

Fig. 2. The two connectors. Left: the current two-pin arrangement, right: the prototype with one pin.

needle inside, both separated by insulating glue. Initial experience with plugging in the pin shows that the single pin version is indeed easier to push in, but remains unfortunately harder to solder to a base board or other components.

3.3 Pin&Play Objects: Notification Pins

Figure 3 shows our current prototype pin, which has at its heart a Time-in-a-Can iButton [6]. It is a self-sufficient component, containing its own battery (3V Lithium: with more than 10 years data retention!), oscillator (32768 Hz), memory (4096 bits), internal real-time calendar and clock (precision: 2 minutes/month), programmable alarms, and full MicroLAN communications support.

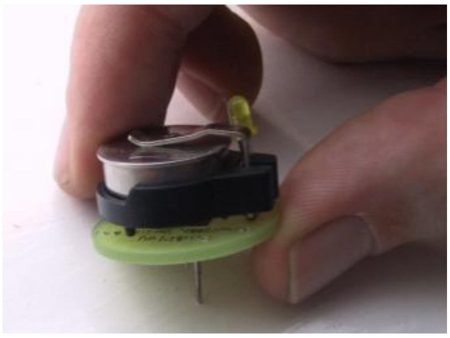

Fig. 3. Close-up of an assembled pin. The current model has two isolated pins for accessing both layers. The one-wire switch is hidden behind the i-Button's connector.

The pin is, in contrast to other miniature devices from similar research projects, reasonably cheap and robust. The total sum of required components for one pin is less than 10 US dollars at a thousand pieces, using the current retail prices. Additionally, the rigid structure of the main component (i.e. an iButton, embodied in stainless steel) ensures reliability and a long life time despite it being a prototype. The tiny dimensions of especially the Time-in-a-Can iButton (1.6 cm diameter, 0.6 cm height) produce a total size of a Pin&Play pin that is close to its traditional equivalent.

The pushpin further contains a LED that can be switched by a 1-Wire MicroLAN-compatible switch. Connecting a single pushpin hence introduces two devices into the network that are just *physically* bound in the same package. The Time-in-a-Can component has internal memory, where it has stored its partner's unique address, so both components can be bound together in virtual space as well.

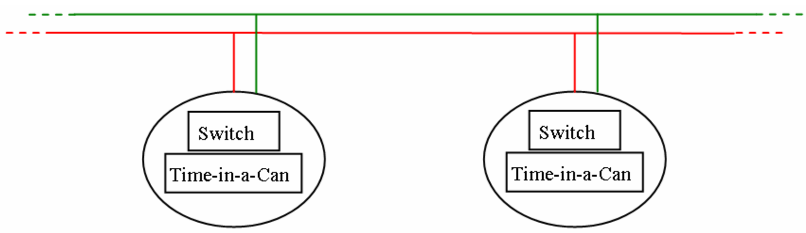

Fig. 4. Network representation of two pushpins, resulting in 4 networked devices. Each device in the network needs one connection to a common ground layer, and one to a data/power layer.

The Pin&Play notification pin is, just like its traditional counterpart, completely independent of the corkboard since it stores and updates all necessary information locally and is self-sufficient. It will work on another corkboard as any other pin, and is augmented provided the board is Pin&Play-enabled.

3.4 Pin&Play Network: The MicroLAN network

To facilitate implementation of all components, the Dallas MicroLAN was chosen as the base communication layer, as it is an inexpensive and flexible networking standard, only requiring a single wire plus a ground reference. According to the reference manual it is able to support networks with a length of more than 300 meters without any repeater or signal regenerator [1]. A large variety of network components is available and range in application from simple identification devices, read/write memories, to sensors and switches.

MicroLAN makes it is perfectly possible to build large tree-structured networks with many components that can be dynamically added or removed, it supports interrupting and requires a pull-up voltage between 2.8 and 6 Volts. This scalability and flexibility comes with a price though: the maximum communication bandwidth is only 16300 bits per second. The structure of the MicroLAN is furthermore a master-slave architecture, only allowing multiple masters using special notification methods. If one compares these properties with the network requirements pointed out in the second section however, an excellent match can be seen.

The network controller could be seen as just another pin, accessing both layers to provide the essential power and communication to the board. Although implementing the network controller embedded like this is not unimaginable, a MicroLAN to serial interface is used at the moment to let a regular PC control the network.

The aim of the network controller software is to find out what pins are plugged in, what components they contain and what they expect from the network. When one of our current Pin&Play pins is plugged into the board, its switch and Time-in-a-Can get powered and provide the MicroLAN's network master with unique identity codes and descriptions for both components. The associated components' unique identity codes are read from the addresses in the RAM memory of the Time-in-a-Can components. This enables the reliably linking of the Time-in-a-Can iButtons and the switches that are packaged into the same pushpin, and avoids conflicts if two or more pins get attached in approximately the same time-window. After this initialization process, information or tasks in the iButtons' memories could be read and executed, and the switches can be controlled.

3.5 Application Scenario: Pins with a deadline

The notice board is but one application of Pin&Play technology, however it can also be seen as platform in itself, with a potential for different kinds of application. The application scenario introduced in this section makes full use of the real-time clock, calendar and alarm functionality in the Time-in-a-Can, and the on-board LED as a notification means to alert the user. With minor changes in infrastructure however, the pins could be used in different ways or they could be modified slightly to come to a new application. We provide in this subsection a typical example of usage for our proof of concept, illustrating the straightforward interaction interface and the preserved concept of the traditional pin board and its pins.

The application is taken from the observation that many notice boards are cluttered with aged and expired notes that should have been removed long ago. Since the new Pin&Play pins have a build-in real-time clock and calendar plus an alarm interrupt, they can be set to a certain date when the document they attach to the board expires. Once the document expires, the alarm triggers the LED on the pin to notify the user that it is safe to remove the current document or note. To keep things clear for the user and prevent all pins from flashing together, a priority is also build in so that only the one with the highest priority will be able to activate its LED.

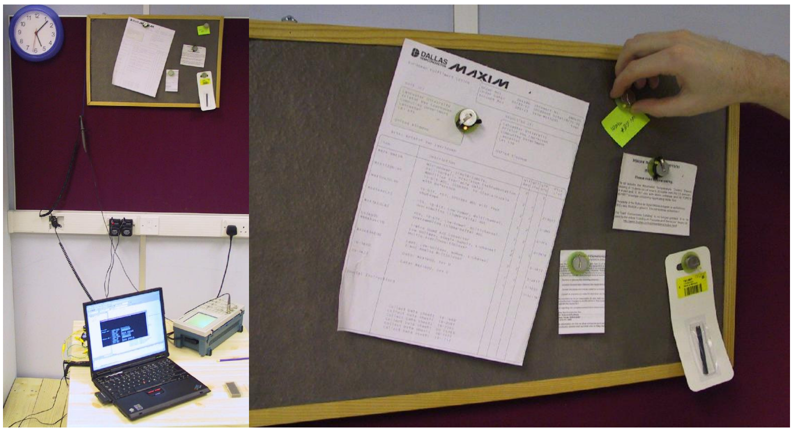

Fig. 5. The two layers of the board are connected to a computer (left), on which the software runs that acts as a master for the network. New documents can be added by pinning them in (right). A pin will start flashing its LED (see upper-left pushpin) when a document expires (i.e. when the pin's alarm flag is set) and no other expired documents have a higher priority.

Figure 5 depicts the current working prototypes of both notice board and pins in action. As mentioned before, the act of introducing the new pin object into the network is done by merely pinning it to the board. With the current implementation, registering new pins, checking the alarm flags and priority, and activating switches takes less than a second.

4 Conclusions

The Pin&Play idea proposes to enable walls in everyday environments as network media, using pins as physical connectors to provide a network bus, power and physical attachment for everyday objects.

We demonstrated feasibility of the concept by augmenting a conventional corkboard and pins with computing and networking capabilities. The pins are capable of alerting users when the note they attach is expired and they can resolve amongst each other who has the highest priority to actually signal the user first. Both pushpin and board are inexpensive and easy to construct, as it is founded on established off-the-shelf network technology components. Future work will involve construction of prototypes in different application domains to demonstrate the versatility of the Pin&Play concept. One targeted domain is network provision through the wall to home controls, to empower users to freely arrange switches and actuators in their environment.

While Pin&Play is based on an innovative combination of technologies, we consider its main contribution to be its consideration of use in everyday settings. It relates to people's use of surfaces such as walls and boards to design their personal and shared areas, to spatially arrange artefacts, and to organise information. It combines the embedding of information technology in the fabric of everyday life with user-friendliness through the use of familiar concepts.

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