A Surface-based In-House Network Medium for Power, Communication and Interaction

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ABSTRACT

Recent advances in communication and signal processing methodologies have paved the way for a high speed home network Power Line Communication (PLC) system. The development of powerline communications and powerline control as a cost effective and rapid mechanism for delivering communication and control services are becoming attractive in PLC application, to determine the best mix of hard and software to support infrastructure development for particular applications using power line communication.

Integrating appliances in the home through a wired network often proves to be impractical: routing cables is usually difficult, changing the network structure afterwards even more so, and portable devices can only be connected at fixed connection points. Wireless networks aren't the answer either: batteries have to be regularly replaced or changed, and what they add to the device's size and weight might be disproportionate for smaller appliances. In Pin&Play, we explore a design space in between typical wired and wireless networks, investigating the use of surfaces to network objects that are attached to it. This article gives an overview of the network model, and describes functioning prototypes that were built as a proof of concept.

The first phase of the development is already demonstrated both in appropriate conferences and publications. [1] The intention of researchers is to introduce this work to powerline community; as this research enters phase II of the Pin&Play architecture to investigate, develop prototype systems, and conduct studies in two concrete application areas.

The first area is user-centric and concerned with support for collaborative work on large surfaces. The second area is focused on exhibition spaces and trade fairs, and concerned with combination of physical media such as movable walls and digital infrastructure for fast deployment of engaging installations.

In this paper we have described the functionality of the Pin&Play architecture and introduced the second phase together with future plans. Figure 1 shows technical approach, using a surface with simple layered structure Pushpin connectors, dual pin or coaxial.

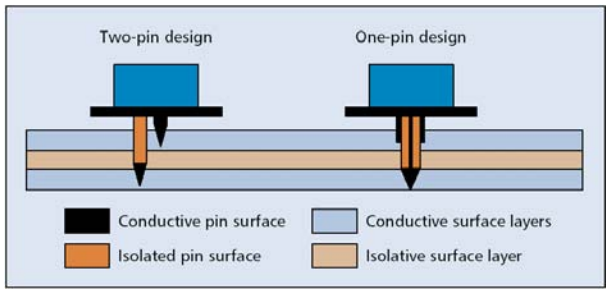

Figure *1* *Surface with Pushpin connectors, dual pin with a simple layered structure*

INTRODUCTION

The most common home appliances (e.g., refrigerators, TV sets, hi-fi systems, game consoles) are relatively large in size and usually remain in the same spot for long periods. It is therefore obvious and worthwhile to provide a wall socket that gives them power and networking. However, a lot of appliances we use in our daily lives are used in different rooms and corners of the home. Many of these are furthermore small in size, and their form-factor makes it difficult to plug them into a wall socket, or to supply them with a cable and connector. Cradles or docking stations provide a means of networking devices like mobile phones, personal digital assistants (PDAs), digital cameras, or laptop computers, but these are different for each device and are

not usually omnipresent in the home. Although wireless networking is becoming more popular in the home, it still lacks some essential features. Wireless transmission first of all costs energy, which means that batteries are required that need to be recharged or replaced at certain intervals. This "feeding" routine also becomes more tedious as the number of wireless devices increases. A second problem is transparency, it is no longer obvious what is networked and why; a natural structure of the wireless network is lacking.

The objectives of the initial investigation were to demonstrate technical feasibility, to assess scalability, and to probe into application potential and user acceptance. The key project achievements were the development and demonstration of Pin&Play hardware and software components, thereby establishing technical feasibility and providing a platform for full-scale investigation. Pin&Play research focus is towards a completely new type of network and interaction infrastructure for augmented environments. The core idea is to provide power, ad hoc networking, and interactive behaviour through augmented surfaces, such as walls and ceilings in architectural spaces, partitioning panels and structures in temporary installations, and purpose-specific surfaces such as message boards. The focus has turned to augment these surfaces with embedded technology to provide power and networking to computational devices that become attached. Computational devices connected to this surface-based infrastructure can include future version of objects commonly attached to walls, panels and boards (e.g. switches, pictures, notes) as well as emerging ubiquitous computing devices (e.g. interactive devices, embedded devices, sensors, beacons, small displays). This infrastructure concept builds on the natural and transparent physical relationship of objects arranged on surfaces. The vision is that any computational object and device that becomes physically attached to a surface also becomes ad hoc networked through the surface. Figures 2 and 3 show Pin&Play connectors, smart pin for interactive surfaces.

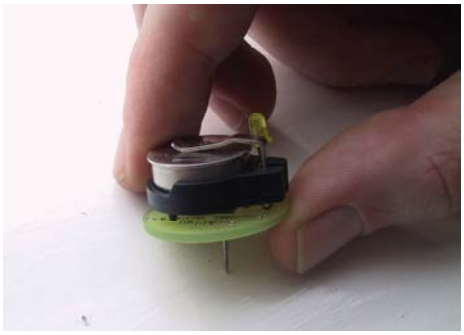

Figure 2 *Application Devices with LED*

Figure 3 *Application Device with pins*

The technical approach toward this vision is to develop a novel network technology – Pin&Play - that uses a new type of physical medium and a new physical connector concept to provide power and networking to communication endpoints. The physical medium is based on conductive sheets that are designed to be embedded invisibly in common surfaces. The sheets are composed of layered conductive and insulative materials as medium for power and data transmission. The connectors are based on common devices for physical attachment to walls, panels and boards, such as pushpins and wall fixings (e.g. screw and plug).The connectors are designed to build on familiar ways of attaching objects to surfaces whilst in addition providing network connectivity to the embedded sheets.

OBJECTIVES

The use of surfaces as a ubiquitous computing is the primary objective of the Pin&Play research is to assess a radically new idea for network provision to computational objects in everyday environments. The core components of the idea are a network surface composed of conductive and insulating layers, and physical connectors based on simple pushpins for flexible and familiar attachment of objects. The surface material is designed to be invisibly embedded in common surfaces such as notice boards or entire walls to transform these into a digital communication medium. The pushpin connectors are designed for augmentation of arbitrary physical objects with embedded computing. They provide a familiar mechanism to users, facilitate flexible socket-less network connection and merge physical and digital attachment to a Pin&Play enabled surface. From analysis of results obtained in our primary assessment project, we conclude that the Pin&Play approach is definitely feasible and very promising. The assessment strongly indicates that Pin&Play is not only scalable as network approach and met with user

acceptance as interactive technology but also indicates that the approach is versatile and that it has potential for a wide range of applications.

PLC & PIN&PLAY

PHASE II

The principal aim is to investigate power technology, network protocols, and communication architecture for more efficient power and data transmission over Pin&Play, and to understand limitations and implications. The concrete objectives are:-

Characterise the network medium in terms of network parameters (capacitance, inductance, damping, type, frequency) and power transmission capability as basis for protocol design.

Design more efficient communication architecture and protocols for communication over DC power

Explore communication over AC/HF power and integration powerline infrastructure

Assess electromagnetic interference and ensure compliance with safety regulations.

DESCRIPTION OF PHASE II PIN&PLAY

The research aims to follow two largely separate strands, one focused on iterative development of Pin&Play communication architecture over DC power for use in prototype releases and deployments, and the other focused on fundamental exploration of Pin&Play communication over AC/HF power and integration with powerline infrastructure. The concrete tasks are:

- Redesign communication over DC based on analysis of physical network parameters to allow more efficient (power & bandwidth) communication without signal loss on larger Pin&Play surfaces.

- Redesign in accordance with EMI regulations (European standards EN 50081/82, EN 61000)

- Create a working prototype of the Pin&Play DC-based network for use in demonstrator

- Investigate power supplies and transformer technology in terms of available power, EMC and noise, and assess and evaluate the design and implementation options for AC/HF power and data transmission (based on modelling and prototyping of various options)

- Designing a communication system (physical data transmission, communication primitives, communication setup and termination, addressing) that exploits the characteristics of the Pin&Play medium

- Design and development of a reference implementation of an open communication protocol stack for DC based communication.

- Create a working Pin&Play network based on AC/HF for lab-based demonstrations

- Continuous assessment of anticipated and developed technologies with regard to safety and compliance with standards for recommended emission (EN55011-22 for conducted and radiated noise and EN60555-2 for low-frequency harmonics.

FUTURE BENEFITS

The technology has the potential to contribute to all aspect of life; intuitive networking of devices through everyday environments can facilitate services and interactions that contribute to better quality of life in home, work and public places. For example, information services become accessible through common surfaces. Moreover, the use of natural affordances in the structure of our environments in Pin&Play systems contributes to user-friendliness of augmented environments. Users also become more empowered through provision of easy-to-use concepts for connection of objects and devices to digital infrastructure.

Pin&Play will enable new health and safety related services, for example in augmented care environments and in network-enabled homes of citizens with special needs to boost their safety and independence. Pin&Play infrastructure in such environments may specifically be used as backbone for sensors and ambient intelligence, for example to automatically detect and alert critical situations. Pin&Play with its facility for dense networking of nodes such as sensors can also enable new approaches to monitoring of safety critical environments.

PIN&PLAY ARCHITETURE

Outcome of the PHASE I

Pin&Play is based on the vision that walls and other surfaces can be used as a bus network for objects that

become attached to them. This is a vision that requires a novel network composition, and is concerned with qualities not typically considered in networking.

Figure 4 *The computer connected to the board, acting as the bus master, switches the pin's light on and off to attract attention*

Pin&Play *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 devices. Instead of wires, it uses conductive sheets, as the objective is to facilitate entire surfaces as two dimensional networks. As solid sheets would leave holes when pin-shaped connectors are inserted and later removed, woven fiber sheets [3] 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 the resistance and especially capacitance can be expected to hinder communication. 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 (e.g., avoiding subdivision into tiles) to support our vision of deployment in everyday environments such as the home.

Deployment of the surface material could, for instance, be envisioned in the form of smart lining under standard wallpaper in the home, to enable entire walls to act as a 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 socketless). Second, 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 an adapter rather than a 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 to 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, to picture frames, artwork, wall calendars, clocks, light controls, and so on. Second, 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 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 furthermore 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.

APPLICATION POTENTIAL

Communication		Interaction	
Ubiquitous	**Wearable**	**Sporadic**	**Intense**
Home Networking	Networked Clothing	Message Boards	Collaborative Scheduling
Power/Comms Infrastructure	Connectivity Wear. Devices	Added Functionality	Task Efficiency

Research Strategy

- Broad investigation to establish versatility
- Focussed study of selected use case

Explored design space and drivers

Figure 5 shows temperature Jacket Scenario, connecting sensors attached to clothing thus exemplifying network provision to wearable components.

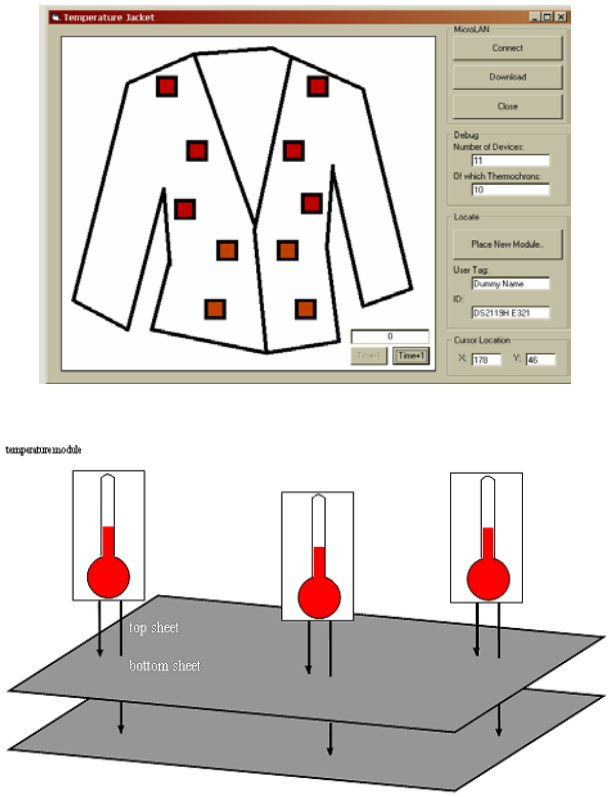

Figure 5 *Temperature Jacket Scenarios*

CONCLUSIONS

We introduced the concepts of the Pin&Play technology to date. Pin&Play is a truly novel and original idea for embedding power and network infrastructure in augmented environments.

The phase one of this project has already been realized, project aimed at developing a highly integrated bus network in both office and domestic environments. Even tiny devices can be wall-mounted by means of pin adaptors and a surface with layers of conductive sheets, to gain power and networking capabilities with the freedom of being plugged in anyplace or in any orientation. The use of off-the-shelf components and the MicroLAN network protocol results in robust and small prototypes that are cheap, easy to re-produce, and yet more than powerful enough for many applications we envision. The network can handle hundreds of devices in a small (but two-dimensional) space, which is especially attractive in the augmentation of small and mobile appliances. We describe some working prototypes and design choices during the implementation of augmented pins and wall-mounted switches.

FUTURE WORK

This article introduces phase two of the Pin&Play development, where our technical approach is to develop a novel network technology that uses a new type of physical medium and a new physical connector concept to provide power and networking to communication endpoints.

Our intention is to apply research knowledge and expertise available to date within the powerline community and ISPLC gatherings to investigate power transmission and communication subsystem which will be based on two strands of investigation. The first one is to develop efficient power and data transmission over DC, and the second one is to explore communication over other power systems (AC/HF).

Power provision was not a driving consideration in the initial assessment however it has become clear that power transmission through everyday surfaces is a highly relevant contribution in its own right. From a computing perspective, power used to be available wherever computing was needed (as either computers were mains connected themselves, or embedded in mains connected appliances), but as we begin to embed computing more deeply throughout our everyday environments power has become a key design concern. In this respect, Pin&Play provides a very original way of addressing power concerns for smart objects that become

routinely attached to surfaces. From a different perspective, the Pin&Play concept has already raised interest in the powerline communications community. PLC is an established technology for data communication over electricity supply grids to mains-connected appliances. [4]
The Pin&Play approach holds the potential to extend the reach of PLC to pervade further into everyday environments. Attractive scenarios include for instance powerline-connected sensor networks in the home which would enable the utilities to develop novel types of service for their customers. It also looks a very attractive concept when considering architectural construction of Intelligent Wall Surface Networks (IWSN) for smart buildings of the future, where it will certainly be adopted within the home automation and in-house networking scenarios.

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ADDITIONAL READING

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