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HOME NETWORK INFRASTRUCTURE FOR HANDHELD/WEARABLE APPLIANCES

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Abstract

A server infrastructure allows wireless wearable appliances or portable handsets to access consumer services offered via the server. Services are accessed via a Universal Home Services Interface (UHSI) which is shared by all access devices. The UHSI can include a voice-activated interface to simplify usage from non-graphical terminals. In a home network the infrastructure resides on a home gateway or central home computer and allows users access to local subsystems or external WAN services. An implementation based on a Universal Plug and Play (UPnP) home network is described.

1. Background

There have been many advances in Home Networking over the past decade. There are now many different ways and means to interconnect and interlink consumer appliances in the home environment. New physical layer technologies allow reliable data transfer between multimedia appliances at much faster data rates than before and as even simple 8-bit microcontrollers are now able to implement TCP/IP a standard network glue for heterogeneous home networks is emerging.

Early generation appliances typically relied on a hard-wired connection to a desktop computer in order to communicate with the outside world, but most present-generation appliances have their own inbuilt communications transceivers: infra-red, 802.11b, Bluetooth or GSM/GPRS. With each new generation home appliances will become more independent and capable. In this context of a new generation of mobile heterogeneous appliances we can see a rapidly emerging need for the users of such devices to gain access to new multimedia and data services. Hence we predict a need for a new broadband infrastructure to enhance the capabilities of such devices. Where better to start with such an infrastructure than in the user's home?

A number of today's home networking technologies offer the infrastructural capabilities to allow home appliances to interconnect and interoperate with each other. Examples include Universal Plug and Play (UPnP) the Open Services Gateway Initiative (OSGi), the Home Audio/Video Initiative (HAVi), and the Java-based JINI technology. However, all of these technologies share a common flaw – they are designed from the “bottom-up” to accommodate the interoperability of devices with other devices. Ultimately, however, all home network devices and services must interoperate with a single master device – the consumer.

We believe that it is most important to simplify and unify the interfaces between the home network and this most important master device. Hence much of the focus of this paper will be on the structure, design and implementation of a single, unified and universal interface to the home network.

2. Overview

In this paper we propose a server-based infrastructure to provide services to users of a wireless home network from their PDA, mobile phone, or even a wearable appliance. Our vision is that modern PDA's and mobile phones will evolve into wireless data-access and entertainment control terminals and that much of the computing power accessed by consumers in the home will reside on a central home gateway server. This server will control much of the multimedia and entertainment systems in the home and could also provide a range of home automation services, and access to broadband Internet services. The data/service-access terminals are in most cases relatively simple devices serving only to provide a user-interface to the main service infrastructure supported on the server. An overview is presented in Fig 1 below.

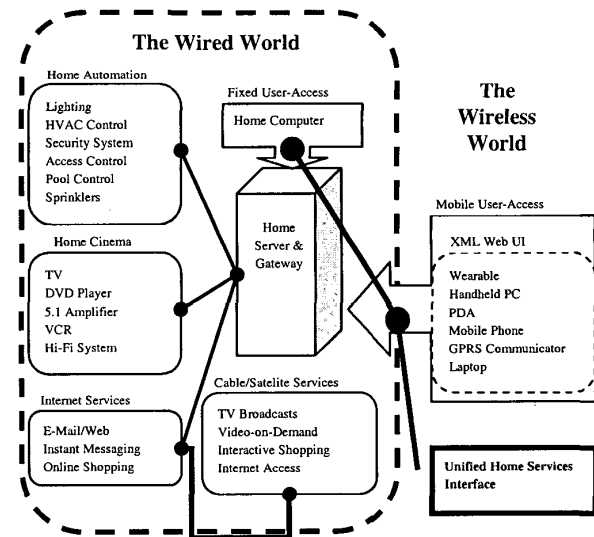


Fig 1 User access to a Home Network and its related services via a common, unified User Interface available on a range of mobile and handheld devices.

A key component of this infrastructure is a common unified home services interface (UHSI) to the home server. This is shared by a home-PC and other user access devices in the home. We believe that it is most important to simplify and unify the interfaces between the home network and that most important master device – the consumer. Hence much of the focus of this paper will be on the structure, design and implementation of a single, unified and universal interface to the home network. This single interface may be exposed to the end-user in many varied formats, but retains the same base set of commands in each format.

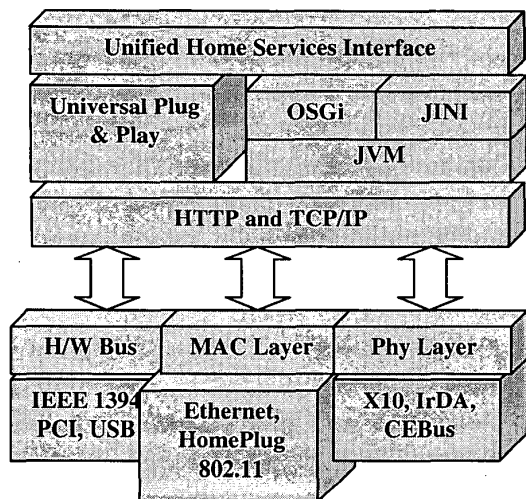


Fig 2: Architecture of the Home Network Infrastructure.

3. Home Network Infrastructure

The core architecture of a home network is illustrated in Fig 2 above. Network devices may be connected over a range of TCP/IP compliant physical media. Other non-TCP/IP devices may be connected through proprietary network bridges. Most devices will implement an additional application-layer protocol to provide specialized device-oriented home networking services such as *Discovery*, *Description* and *Eventing*.

Ultimately our goal is to provide a UHSI layer with can access devices using all the major home networking technologies – UPnP, OSGi, HAVi and JINI. However, to provide a working proof-of-concept we have currently restricted ourselves to implementing only a UPnP interface for the UHSI. It is useful at this point to give the reader a quick overview of UPnP.

3.1 UPnP Server Infrastructure

Universal Plug and Play (UPnP) is an architecture for pervasive peer-to-peer network connectivity of intelligent CE appliances and wireless devices. It leverages TCP/IP to enable control and data transfer among networked devices in the home. Key features of UPnP are:

- No device drivers - common protocols.
- Media and transport independent.
- Leverages HTTP and browser technologies.
- Agreed base protocol sets on a per-device basis.

UPnP enables data communication between any two devices under the command of any control device on the network. It supports zero-configuration networking and automatic discovery whereby a device can dynamically join a network, obtain an IP address, announce its name, convey its capabilities upon request, and learn about the presence and capabilities of other devices. Furthermore, a device can leave a network smoothly and automatically without leaving any unwanted state behind.

Clearly UPnP provides much of the core infrastructure required by our Home Network Infrastructure. In particular it allows network control devices to establish links with and control other devices on the network. This is extremely useful in the context of our UHSI approach because it allows us to implement a single server-based control device which can gather and collate information about network devices. As this data is provided in XML format it is quite easy to rearrange and manipulate it for the purposes of our UHSI application layer.

3.2 Additional Server Components

Although there have been some recent examples of networked CE devices, particularly in emerging market segments such as Personal Video Recorders (PVRs) there is still a shortage of non proprietary appliances. Thus we are forced to simulate many devices on a home network. Fortunately it is quite easy to create pseudo-devices using a standard PC with an Ethernet or 1394 network interface. Our server provides connectivity to both of these wired networks. In addition we have implemented wireless 802.11b network connectivity and expect to add Bluetooth connectivity in the near future.

Because there is sufficient bandwidth available with today's networking technologies we have focussed on how a futuristic A/V network might function. Thus most of our devices implement MPEG streaming over either TCP/IP or via the IEEE 1394 network.

3.3 Server UI Interfaces

As our core network infrastructure is based on UPnP it is natural that many UI components are exported from the server in a Web based form. However we have implemented a number of other novel interfaces which have certain advantages in some instances. These include a *Virtual Network Computer* (VNC) interface which allow a user to directly access and execute a UI application on the server.

We also invested a significant amount of time investigating practical implementations for a voice-

activated UI. Finally we believe that a generic remote-control interface should also be provided for the base set of A/V device commands. This and other aspects of our UHSI implementation are described in section 4.

4. Unified Home Services Interface (UHSI)

In this section we will describe various aspects of the UHSI. Firstly we begin with some of the philosophy which inspired our approach to the problem. We then explain the concept of *MetaDevices* and the server-side implementation adopted for this work. Finally we describe some of the actual UHSI implementations proposed by this research.

4.1 Overview of UHSI

In this section we develop some ideas regarding current user-interfaces in the home environment and discuss the confusion caused to consumers by the plethora of user-interfaces available on today's consumer electronics appliances. A particular goal of this paper is to examine how a UHSI might be implemented in a practical home network based on today's technologies.

Perhaps one of the most important problems which a next-generation home network should address is that of "remote clutter". Most consumers have become very familiar with this problem over the past decade. A typical modern home A/V system will consist of anything from 3 to 8 separate pieces of A/V equipment. Each of these has its own unique remote control interface and despite a new generation of "multi-device" and "learning" remotes the problem remains a headache for many consumers.

Our second motivation was inspired by the typical usage model for many home systems. In most cases an end-user does not want, or have the time to learn to use advanced features of a new CE appliance. In fact the simpler the operation of an appliance the happier most consumers are. Thus most consumers find the idea of combining appliances to enhance their functionality to be inherently confusing. In order to overcome this barrier and simplify the usage of devices on a home network we introduced the concept of a *MetaDevice*. This is nothing more than a pre-configured combination of devices which performs a single functionality. This is explained in more detail in section 4.2 below. From our perspective the *MetaDevice* allows a single, combined UI to control several distinct appliances. This is illustrated in *Fig 3* below.

4.2 The MetaDevice Concept

As explained above a *MetaDevice* is nothing more than a pre-configured combination of CE devices which performs a single functionality. Let us consider as an example a typical Home Cinema set-up. A standard TV links through an A/V amplifier to a range of A/V

equipment such as a cable-TV box, a DVD player and a VCR.

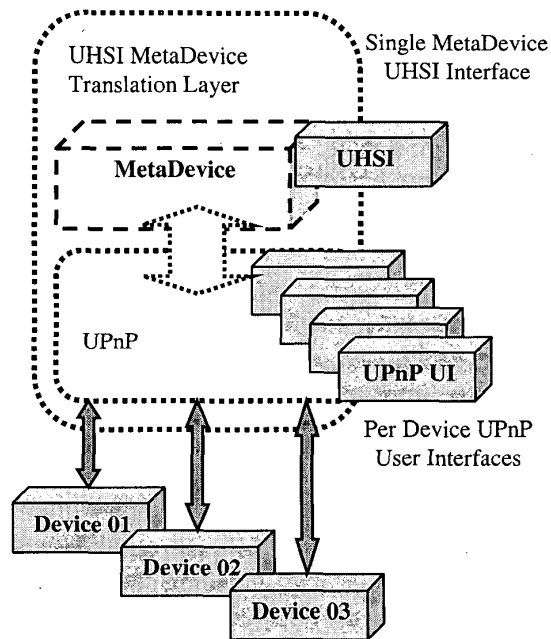


Fig 3: Several Network Devices combine into a single MetaDevice with a common User Interface.

Now in practical usage one of these sources is selected for the A/V input to the amplifier and the TV is selected to receive the output from the amplifier. If the amplifier supports more than a single set of speakers then the appropriate set of speaker for the room with the TV should also be selected. Using today's CE equipment it is necessary to perform these selections on the A/V amplifier and it will still be necessary to control the volume, channel selection, etc, using separate remote controls.

If we now replace today's A/V equipment with networked appliances we can see that we will still need to select several A/V appliances in order to achieve the end goal of activating and viewing a TV channel. This configuration process is somewhat easier in that it should be possible to access a Web user-interface for each appliance over the home network infrastructure. However it will still be necessary to reconfigure each appliance when switching from viewing the TV to playing a DVD or a video cassette.

Now consider that the configuration of each appliance and the various control codes is memorized and stored in a device map as a pre-configured *virtual* device with its own customized UI. To watch TV it is now only necessary to activate the UI for this *MetaDevice* instead of accessing 3 or more separate appliances.

4.3 Server-Side Implementation of Metadevices

This is described in *Fig 4* below. Standard UPnP activity on the home network is unaffected. However a new UPnP control point is implemented by the *Device Broker* software. This behaves like a global UPnP control point which continually updates information about available network devices into a server-side database. Between the UHSI layer and the UPnP device broker is a second application known as the *MetaDevice Agregator*. This application is responsible for storing *MetaDevice* data in a second database – the *MetaDevice Map*. All of this data is stored and managed in XML format.

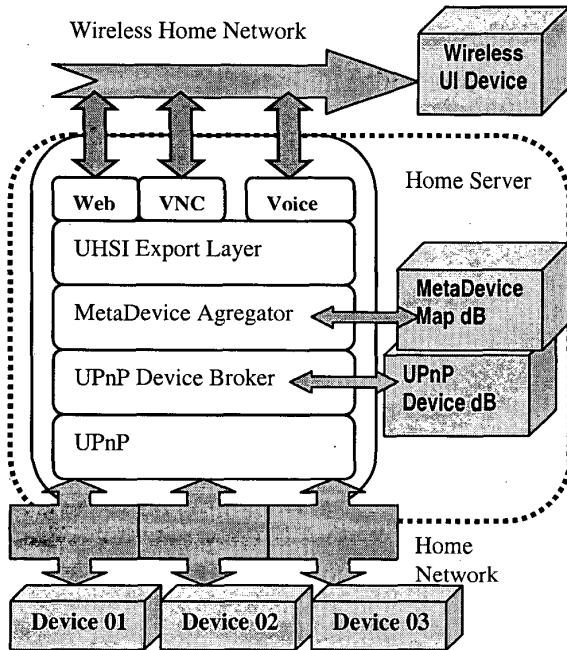


Fig 4: Software Implementation for UPnP MetaDevices.

The *MetaDevice Agregator* is responsible for mapping UHSI commands from a configured *MetaDevice* onto one, or more, actions from an appropriate UPnP service. A set of UHSI commands for a standard *PlayDev* is shown in *table 1*. It should also, in a practical implementation, provide a user-friendly mechanism to configure and manage network *Metadevices*. However, in the current prototype all configuration of the UHSI *MetaDevices* must be performed manually.

A typical example of a basic set of services for a very simple UPnP compatible DVD Player product is shown in *table 2*. This DVD Player must implement all the required embedded devices and services specified herein.

Symbol	Name	Symbol	Name
	MenuMode		Volume Up
	PlayMode		Volume Down
	Up		Brightness Up
	Down		Brightness Down
	Select/Play		Channel Select
	Back		Channel Up
	Pause		Channel Down
	Stop		Disk Select
	Rewind		Disk Eject
	Fast-Forward		Tape Select
	Begin		Tape Eject
	End		Selectt

Table 1: UHSI Icons and the corresponding command names for the standard UHSI PlayDev MetaDevice.

Device Type	Root	Req./ Opt.	Service Type	Req./ Opt.	Service ID
DVDPlayer	yes	R	SwitchPower	R	<u>SwitchPower</u>
			ChangeDisc	R	<u>ChangeDisc</u>
			PlayDVD	R	<u>PlayDVD</u>
			Audio	R	<u>Audio</u>

Table 2: Required services for a UPnP compatible DVD player

Finally, *Table 3* shows how the PlayDVD service defines actions to play a disc, select a chapter to play, and get information about the currently loaded DVD and selected chapter. The mapping between UHSI commands and the PlayDVD actions is given in this table. Note that some UPnP actions are not mapped to UHSI commands in PlayMode, but can map to alternative UHSI commands in MenuMode.

UPnP Action Name	Req. / Opt.	UHSI Mapping
Play	R	Disk_Select
Pause	R	Pause
Stop	R	Stop
GetDiscInfo	R	Info
SelectChapter	R	Select/Play
NextChapter	R	Up
PrevChapter	R	Down
GetChapterInfo	R	Info

Table 3: Mapping of the PlayDVD service UPnP Actions to the Methods of a UHSI MetaDevice in PlayMode..

4.4 Interface Components for Metadevices

In order to activate a particular UHSI command sequence the end-user needs to have access to a UHSI interface. There are a number of different interface modes that were implemented in order to demonstrate the potential flexibility of having a single, centralized point of control for all devices on the home network. From Fig 4 we see that most UHSI interfaces are available in Web form, through VNC as an application running on the server and, thirdly, via a voice-activated interface. In fact a variety of additional scenarios suggest themselves and we will discuss some of these in section 5.

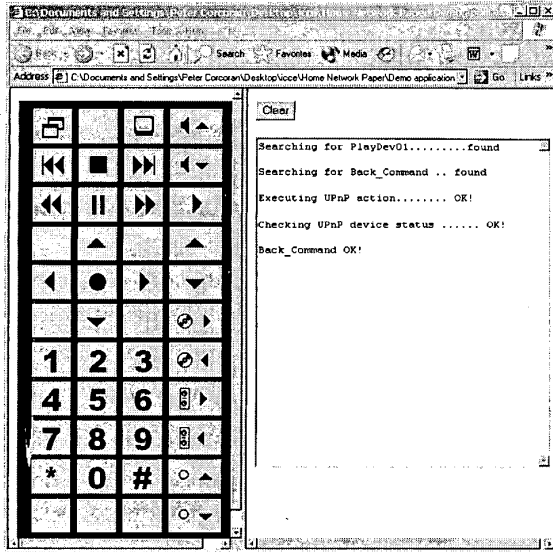


Fig 5: Web Interface for the PlayDev01 Metadevice.

4.4.1 Web Interface

This is currently only implemented in a simple remote-control format. The user is presented with a simple push-button interface as illustrated in Fig 5. A debug terminal can be seen to the right of the actual user interface. This form of interface was chosen as it is very familiar to most users of A/V equipment. Note that here could be a number of alternative implementations of the Web interface for a single *MetaDevice*. Thus, a more sophisticated web interface might offer additional control features and information on a DVD movie or a music track on a CD as the disc is playing.

4.4.2 VNC Interface

The *Virtual Network Computer* is an open-source application which directly exports a desktop from the server as an interactive screen-view. To access the VNC desktop a user need only run a simple client on their access device. Clients are available for a broad variety of devices including handheld PDAs and Pocket-PCs. There are also clients for Linux and a Java applet which allows

the VNC desktop to be accessed from and Java-enabled Web Browser. To use a VNC interface we need to run an application with a GUI directly on the server. In fact VNC allows a remote user to access and edit configuration files and database tables directly on the server, although we doubt that most users of a home network will require such a low level of access to the UHSI system. The real benefits of the VNC interface will become apparent, however, when we describe the voice-activated interface below.

4.4.3 Voice-Activated Interface

In addition to the browser-menu interface we also provide a generic, device independent, voice-activated interface. This is interesting because it allows hand-free operation and allows users a more natural and relaxed means to control their home environment – for example, they can turn a particular *MetaDevice* on and select A/V sources using spoken commands (“*PlayDev Zero-One on*”; “*Channel 106 please*”) without burying their heads in their mobile phone or PDA screen.

Because the main voice recognition is implemented on the server this interface can run on practically any handheld, PDA or phone-like appliance which implements TCP/IP and provides a microphone to enable voice capture. An overview of the voice recognition interface is given in Fig 6 below.

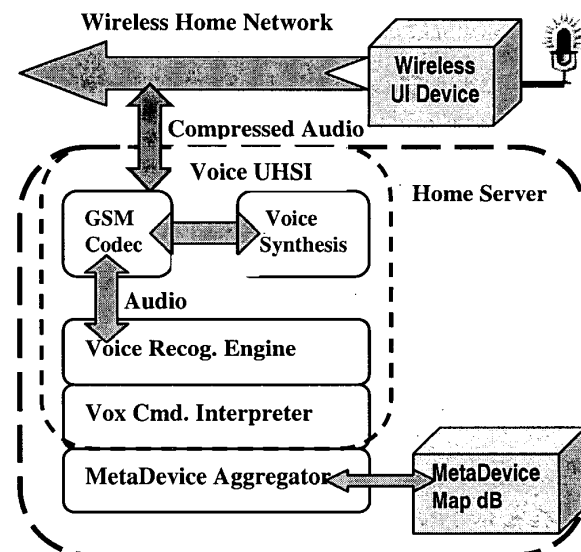


Fig 6: Voice Recognition based UHSI Architecture.

Analog speech is encoded into binary form on a remote PDA and streamed to a TCP/IP socket on the server where it is reconstructed and passed through a standard voice recognition engine. The *Voice Command*

Interpreter extracts a set of *MetaDevice* commands from the Device Map database and maps them onto a valid grammar syntax. It also configures the voice recognition engine and waits for events from the recognition engine. Valid commands are then translated into UHSI commands and passed to the UPnP network layer. Optionally responses can be converted into voice responses using the Voice Text module and transmitted back to the mobile client device via the codec.

A speech grammar is a collection of words, phrases and a set of rules that define all possible valid voice commands that can be accepted. A grammar provides a language model for the recognition engine, constraining the set of words to be considered and therefore increasing recognition accuracy and minimizing computational resources. The Grammar is defined in Java Speech Grammar Format (JSGF).

To reduce bandwidth requirements, voice commands are compressed before transmission. Our prototype utilizes GSM 06.10 compression, a standard used by the GSM digital cellular mobile phone network enabling speech to be compressed to about 14kbps. IBM ViaVoice was utilized as the voice recognition engine. ViaVoice provides flexible APIs which facilitated its use as a voice command recognition engine.

5. Usage Scenarios

From the perspective of an end user they will gain access to the local UHSI, as soon as their handheld or wearable computer connects to the local home network. When they browse to the URL of the UHSI server they will see a Web-based UI similar to that of *Fig 7* below. This presents a device map of the home network. Along the left-hand side is a list of the actual physical devices present on the home network. Across the top is a series of pre-configured *MetaDevices* – *PlayDev01*, *PlayDev02*, etc. Along the bottom of the Web browser is a frame which allows the user to select the room of the house they currently occupy. Any active *MetaDevices* in that room are marked in color as are the associated physical devices which contribute to the *MetaDevice*. Thus one may remark that *PlayDev01* is the main home entertainment system and it uses *SAT_TV01* as its MPEG source while displaying its output on *BigTV01*. It channels the MPEG stream through a home-cinema amplifier *HC_AMP01*.

From the user's point of view they only need to access the hyperlink for a Web Interface at *PlayDev01* which opens a control interface for this *MetaDevice* as illustrated previously in *Fig 5*. Alternatively the user could have selected the Voice-UHSI interface and executed UHSI commands vocally.

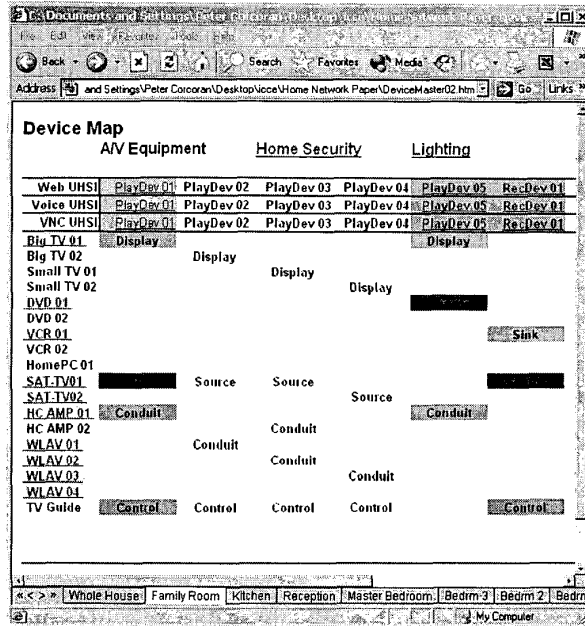
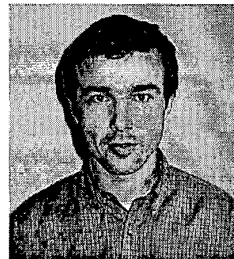
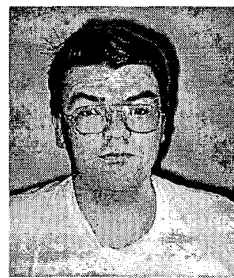


Fig 7: Main UHSI Web Interface with Device Map of real and virtual MetaDevices on the home A/V network.

Author Biographies



Petronel Bigioi received his B.S. degree in Electronic Engineering from "Transilvania" University from Brasov, Romania, in 1997. At the same university he received in 1998 M.S. degree in Electronic Design Automation. He received a M.S. degree in electronic engineering at National University of Ireland, Galway in 2000. Currently he is lecturing embedded systems at National University of Ireland, Galway. His research interests include VLSI design, communication network protocols and embedded systems.



Peter Corcoran received the BAI (Electronic Engineering) and BA (Math's) degrees from Trinity College Dublin in 1984. He continued his studies at TCD and was awarded a Ph.D. in Electronic Engineering for research work in the field of Dielectric Liquids. In 1986 he was appointed to a lectureship in Electronic Engineering at UCG. His research interests include microprocessor applications, environmental monitoring technologies. He is a member of I.E.E.E.