Multichannel Audio Distribution through the IEEE 1394 Protocol. -A Practical Approach-

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Abstract

The aim of this paper is to describe the current state of convergence of different kinds of networks in the home environment. In such a realm the 1394 IEEE Protocol displays itself as the best player between other different technologies. A description of this high-speed protocol is provided. Finally, in this paper we suggest a prototype for multichannel audio distribution using IEEE 1394 and describe the development of the prototype elements.

1. Introduction

New era communication systems say HFC, xDSL, xMDS, have made necessary for our homes to become an extension of the high-speed railroads of the data networks. Advances in digital signal processing techniques and the low integration costs of electronics have made possible the entrance of high-quality and capacity audio-visual devices in our homes. Finally, as users get used to electronic devices they ask for more capabilities in their traditional home appliances, so that they can be remotely controlled or even interconnected.

This way, different kinds of network will have to meet, instead of crossing, within our home. For this aim it is necessary a kind of technology fulfilling the following points:

- It allows the transmission of high demanding bandwidth data as video or real audio, as well as the protocols for its control.
- It allows data flow synchronisation.
- It is widely adopted in the computer industry as well as in the A/V industry.
- It provides a coherent integration of the entire set of computer devices and A/V devices.
- It allows a modular, interoperable, multi-brand system in which devices can be plugged and unplugged with no effort for the final user neither a need for reconfiguration of the system.
- It needs as few controls as possible.
- It allows the maximum operation levels.
- It is low cost, robust and trustful.
- It is standardised by an international standard organisation.

Luckily today there is a standard that complies with all the points above: the IEEE 1394 Protocol. To test the capabilities of such this protocol we describe a prototype for multichannel audio distribution based on IEEE 1394.

2. Information, Audio-visual and Appliance-Control Networks.

As it has been exposed in the previous paragraph three different networks can be depicted in the home environment.
The type of network that is showing the fastest growth is the information network. It is not estrange finding more than one PC in our homes and so linking them is the common use.
Close in the ranking to information networks for the home market are audio-visual networks. Today set-top-boxes are designed as media gateways within our homes, for music and video distribution.
The appliance-control network has been the less demanded one till now.

Table 1 shows a comparison of these three main home networks [1].

These three types of network have been, so far, independent as table 1 shows. But the next step will be its interconnection. And, as soon as these networks are linked to each other, there will be a phenomenal growth in the possible number of combinations of equipment.
As a prelude for this new era, great effort and lots of studies are being made in developing technologies that will easily interconnect home appliances and other equipment in a multi-media home network environment. Equipment manufactures face two problems, namely swapping information between different media and assuring simple connectability. A variety of middleware is being developed based on several platforms: the home audio/video interoperability (HAVi) by Sony Corp and other

Japanese and European AV manufactures; the Jini distributed processing environment by Sun Microsystems Inc; and the universal plug-and-play (UpnP) specification by Microsoft.[2][3][4][5][6][7].

Table 1. A Comparison of the Three Main Home Networks

	Type of Data	Data Rates	Physical Layer Protocols	Transfer Medium	Middleware and API	Home Gateways	Future Products
Information Network	www service,e-mail, control commands, etc.	Dozens of Mbps.	Ethernet, USB, IrDA, Bluetooth	Phone lines, Ethernet twisted pair, radio, infrared.	JetSend, Jini, UpnP	Pc, home gateway, cable modem, etc.	Printers, digital still cameras, scanners, external HDD with Ethernet and USB interfaces.
AV Network	Video data, music data, control commands	100 to 400 Mbps.	IEEE 1394	Metal cable, plastic optical fiber.	HAVi, etc.	Digital set-top-box, home game system, etc.	D-VHS VCR, recording DVD, video recorders with HDD and other devices with IEEE 1394 support.
Appliance-Control Network	Control commands	From hundreds to several thousands of bps.	LONTalk, ECHONET specs	Power lines, infrared.	ECHONET, HAPI, Jaccas, Open-PLANET, etc.	Watt-hour meter, etc.	Universal remote controllers for infrared control of whiteware, air conditioned, etc. with power line communication modules.

3. The IEEE 1394 Standard.

3.1. Origin.

The Microprocessor and Microcomputer Standard Committee of the Institute of Electrical and Electronics Engineers, (IEEE), started on 1986 a process in order to unify different implementations, over a serial bus, of the VME, Multibus II and Future Bus. This effort resulted on the standard IEEE 1394-1995 on the autumn of 1995.

The 1394 serial bus is based on the original FireWire bus, designed by Apple Computer as a low cost substitute for the SCSI bus.

It offers a scalable connection allowing "hot" plugging; nowadays it works with speeds up to 400 Mbps and the next version, IEEE 1394b, defines speeds up to Gbps. A number of 64 nodes may share the bus in a peer-to-peer network without a need for a specific management host. It observes two types of transfers, asynchronous and isochronous, what makes it ideal for real time data transfer (audio, video) as well as other data types.

But this protocol gives also a device powering system what, in combination with its high transmission capacities, makes of it the ideal protocol for the connection of distributed systems. With this serial bus, the final users will be able to connect the PC to its peripherals, other appliances, edit audio-visual contents, enjoy of Internet and much more. The IEEE1394 protocol is going to bring the multimedia world into the home and, allowing experiences not possible till now, it will be the window in our home to broadband systems. The IEEE 1394-1995 has been implemented in electronic commercial equipment. A revision of the standard 1394a is now the version implemented by most of developers. The next step, the IEEE 1394b revision that takes the protocol speeds up to Gbps is already a fact.

3.2. Characteristics.

The main characteristics of the IEEE 1394 protocol are the following [8][9]:

- Automatic assignment of node address.
- The physical layer gives support to cable media as well as to backplane configurations.
- Variable transmission data rates based on rates compatible with ISDN ones, covering the range 24.756 Mbps and 49.152 Mbps for the backplane environment and 98.304, 196.608 and 393.216 Mbps for the cable environment.
- The cable environment allow up to 16 consecutive physical connections, each one up to 4.5 m. long. So, the maximum length between two devices is 72m.
- Transfers in the bus can be reads/writes of isolated quadlets (32 bits data blocks) as well as sets of quadlets. There is an isochronous transmission mode allowing a guarantied bandwidth service.
- There is a fairness bus access method that ensures equity between all nodes.
- This standard complies with the Control & Status Registers Architecture for microcomputer buses ISO/IEC 13213, ANSI/IEEE Std. 1212-1991.

The P1394a (1997) revision introduces some improvements like acknowledge speed up and bus access optimisation. The P1394b revision is still on work and it defines transmission rates in the order of Gbps and link lengths of hundreds of meters by defining new physical media (POF, CAT-5).

3.3. HAVi.

In November 1999 the HAVi Organisation was formed. Digital Harmony Technologies, Loewe,

Kenwood, LG Electronics, Mitsubishi Electric, Pioneer, Samsung Electronics, Sanyo, Seiko Epson, Sun Microsystems, Tao Group, QNX Software Systems, Vivid Logic, Wind River Systems and Yaskawa Information Systems, decided to join in this

consortium with the mission of promote the HAVi architecture for home networking and interoperability of electronic devices and develop interconnection bridges with other home networking standards such as Jini and UpnP.

HAVi adopted the IEEE-1394 bus as the underlying network technology for the HAVi protocol as well as for the transport of real time AV streams. It provides a set of Java APIs for development of applications under this environment [10].

4. Suggestion of a Prototype for Multichannel Audio Distribution.

Here the authors want to present a small prototype that was built to test the capabilities of IEEE1394 for the distribution of multichannel digital audio [11]. The extremely good quality of the results makes it reasonable the expansion of this prototype and the integration with HAVi.

4.1. Transfer Services.

As it has been presented before, the IEEE1394 standard allows two basic data transfer types:

- Asynchronous Transfer. - It provides a protocol for the distribution of packets of variable length to a specific address that responds an acknowledgement.

- Isochronous Transfer. - It provides a protocol for the distribution of packets of variable length, in broadcast for all nodes in the bus and at regular time intervals.

During a nominal cycle of 125μs., a maximum of 100μs. is dedicated to isochronous transmissions [8] being the rest for asynchronous transfers if any. If there are no asynchronous transfers pending in that cycle, the whole nominal cycle may be used for isochronous transfers. Different isochronous flows may be transmitted in a nominal cycle forming what the standard defines as isochronous channels. When all these isochronous channels have been transmitted, the asynchronous transfers start.

The prototype described here, is based on these transfer modes, so that, it uses the isochronous transfers for data flows, while asynchronous transfers for command and control of the receiver devices.

4.2. The prototype.

The scheme of the prototype is presented in Figure 1.

A personal computer acts as audio server. It transmits through the IEEE1394 bus the different digital audio channels. Autonomous receivers, attached to the bus as IEEE1394 nodes, are responsible for choosing the channel their users want to listen to. Duties of the receivers are also the processing of the digital information (decoding, decompressing, etc.) and finally playing the sound channel.

5. Development of the Prototype Elements

To build up the prototype, commercial solutions from Texas Instruments were used: the TSBKPCI and TSBKPHPRL development kits described in the following paragraphs.

5.1. TSBKPCI.

TSBKPCI is based on the TSB12LV21A (PCILynx) link-layer controller chip and the physical layer chip TSB21LV03. They both together join to form an easy platform in order to bridge the PCI bus and the IEEE 1394 serial bus.

An EEPROM allows saving the configuration registers of the TSB12LV21A. TSBKPCI provides a programming environment for application development, based on a C library (Lynxsoft API) that defines data structures and the sequence of calls with the control procedures necessary to make the IEEE 1394 transmission.

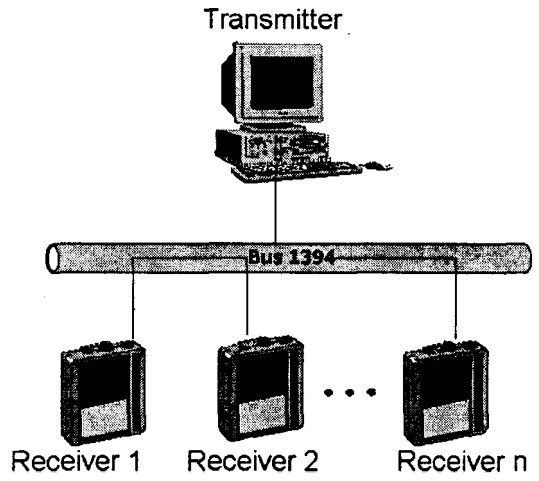

Figure1: Prototype Scheme

5.2. TSBKPRPHRL.

The TSBKPRPHRL card, is the base of the autonomous receiver. It is based on a C5x DSP from Texas Instruments, the TMS320C52 DSP, and the integrated circuits TSB11C01 and TSB12C01A in order to support the IEEE1394 transmissions and receptions.

A complex PLD, a MACH445 integrated circuit, provides the necessary control to the design by

allowing a single DMA channel that transfer data from the DSP and the SRAM and Flash memories integrated in the board.
A D/A converter, the TLC320C46, controlled by the DSP allows the conversion and playing of the audio channel selected by the user.
So the transmitter is a PC, based on an application developed for the PCILynx card (TSBKPCI), while the receiver is formed by the TSBKPRPHRL card, that based on the DSP, is responsible for unpacking the IEEE1394 data, processing it and playing the audio channel through the DA converter.

5.3. Application for Multichannel Audio System

5.3.1. The Channel Concept.

As defined by the standard, each of the audio channels should be incorporated within different isochronous channels, what would mean an increase in the unuseful data (CRCs, packet headers) resulting in inefficiency. Even though, it is not possible to know, a priori, the number of audio channels that will be on the bus and, if this number is bounded the system capacity may be poor.

We solved this by creating one and only synchronous channel, allocating the information of the different audio channels within. The redundant information, of headers and CRCs, is due to only one isochronous channel. The rest of the time may be used for carrying useful audio data [11].

5.3.2. Flow Control.

The problem of the flow control, in order to avoid flooding the storage capacities of the TSBKPRPHRL card is solved by means of asynchronous transmissions from the audio receiver to the audio server, demanding or stopping the data flow depending on its processing status and capacities [11].

6.Conclusions.

We have tried to expose the current state of convergence of the Home Networking environments. In such a state we consider that a bet should be made on IEEE1394 solutions and to test it we developed a prototype for audio distribution. The results obtained with this prototype were quite satisfactory in the transmission of multiple PCM audio data channels as to extend the prototype design for MPEG audio flows.

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