Integrated Multimedia and Sensor Data Management in Heterogeneous Home Networks: a Concept Proposal

Susanna Spinsante, *Member, IEEE,* Ennio Gambi, *Member, IEEE*

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***Abstract*—Home Area Networks designed for the delivery of both multimedia contents (e.g. TV programs, movies, music) and home automation services (e.g. household appliances commands, lighting and surveillance controls) are becoming widespread, especially thanks to the latest developments in wireless sensor and communication devices. This kind of networks, however, represents a new challenge for the networking field, particularly with respect to the integration of many different home and building automation solutions, that are not originally conceived to coexist and exchange data. Consequently, it is necessary to introduce an operational infrastructure able to interconnect different devices on the same communication link, or over different links, by means of a single user interface and a unified intelligence, thus making possible a complete and efficient management of the system. This paper outlines the main components in the design of an integrated home network architecture based on both commercial and customized devices developed ad-hoc, and provides preliminary results about the performance obtainable in the delivery of different data flows. The convergence of many differentiated services over IP-based architectures dramatically increases the amount of IP traffic to be delivered to the clients, so that Quality of Service management issues arise, and are to be taken into account.**

***Index Terms*—Home Area Networks, sensor, multimedia, integrated management.**

I. Introduction

THE definition of Home Area Network (HAN) refers to a network located and limited within a single house, and at present, given the dominating trend, it translates into an IP-based network covering the whole premise, and conveying all kinds of user services [1]–[3]. Modern houses are requested to be equipped with digital control systems for functional services, like household appliances, lighting and surveillance. Moreover, digital entertainment contents are expected to be available in each single room, such as, for example, digital radio and television services, personal movie and music collections, and others. In addition, Internet-based communication services, such as IPTV and Voice over IP, are becoming widespread, so broadband connectivity is now an ubiquitous requirement. All this pushes to design solutions able to convey many differentiated services over IP-based networks, with favorable cost to benefit ratios [4], [5]. Among the several research activities promoted in the field of HANs for media delivery, the European project OMEGA [6], [7] is investigating a possible hybridization of network technologies for future entertainment services, through the design of a so-called Inter-Medium Access Control (MAC) layer. Many efforts have been made to converge heterogeneous physical technologies into a single coherent framework, but no impacting solutions have been achieved up to now. The targeted architecture is a Gbps-capable home network, necessary to ensure the Quality of Experience expected by the user, built upon radio links combined with a Power Line Communication (PLC) - based backup infrastructure, in such a way as to not require any "new wires" within the home.

Besides entertainment services, home automation facilities represent a fundamental requirement for modern buildings and houses. Many standards have been released for the exchange of home automation data, as, for example: European Installation Bus (EIB), European Home System (EHS), Open Services Gateway Initiative (OSGi), Home Audio Video Interoperability (HAVi), and others. Furthermore, industrial protocols can be adapted to fit home automation applications, such as, for example, DeviceNet, Profibus, CAN and RS485 standard protocols. They are conceived for short-distance and low-cost connectivity of sensors and actuators, so they fit well to the context of home networking applications. Any home automation solution has to satisfy some basic requirements to ensure the user's comfort and trust. Among them: easiness of use, service continuity (i.e. very low failure probability), reliability, and limited costs. Once these goals are satisfied, a properly designed home automation solution may also allow energy saving, besides a comfortable and performing management. The main elements in home automation are sensors and controllers. Sensors monitor different parameters related to the home environment, and translate their variations into correspondingly varying signals. Controllers process signals generated from sensors and user's configurations, and send proper commands to the actuators located in the home environment.

To convey different data services over IP, such as home automation and multimedia services, gateways must be provided, that adapt automation data transport to IP based networks, and allow an easy management of the connected devices, both from the inside, and from remote networks. Home gateways shall connect the external access network and the internal heterogeneous home network, and deliver services to the home environment. Different consumer hardware platforms may compete against each other to become the selected home

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S. Spinsante and E. Gambi are with the Polytechnic University of Marche, Ancona, Italy. (email:{s.spinsante, e.gambi}@univpm.it).

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gateway device, or a new equipment, designed ad hoc to perform gatewaying, may be proposed. In the scenario herein discussed, standard PC based architectures act as gateways or servers in the heterogeneous HAN, given their flexibility, and the possibility of platform expansion by additional Peripheral Control Interconnect (PCI) boards, like those used to receive and decode digital video signals from DVB-T and DVB-S transmissions.

In an integrated home automation and entertainment scenario, Quality of Service (QoS) provisioning is of central importance to ensure correct operations, and to face the possible occurrence of congestion conditions. QoS becomes a fundamental issue when several streams, carrying both control data and multimedia applications, with different time, priority, delay, and rate requirements, must be transferred over a local area network including heterogeneous devices [8], [9]. Several figures may be defined in order to assess the level of QoS supported by a given network. Dealing with networks in which building automation data are to be delivered together with video streaming data, the QoS ensured to the latter may be expressed through IP transport related parameters, such as percent amount of dropped packets and out-of-order packets (at the receiving node), percent amount of corrupted packets, delay and jitter. The last figure may be further detailed into average jitter and interarrival jitter, that are estimated in different ways at the receiver.

In this paper, we consider an IP based HAN [10], in which entertainment and home automation services must coexist, in order to provide the users with unified access and control stations, for either enjoying entertainment applications, exploiting the delivery of home data (such as video surveillance streams), and performing the control of home facilities and appliances. A possible architecture to implement this kind of network is considered, built upon a centralized framework with a unique server platform. This solution is based on common commercial hardware and open source software, suitably modified and adapted to the target application. Support for QoS [11] relies on the implementation of an open source QoS router, able to differentiate services and related streams, and to impose proper rules for their associated priority and bandwidth. About the delivery of entertainment services, the focus is on the redistribution of DVB-T channels to the users located in different rooms, through the encapsulation of each channel data into IP packets, and their streaming over the home network. Streaming DVB-T signals is of interest, because digital terrestrial television represents the last development of the traditional, analog broadcasting, and it is spreading fast, as shown by its growing penetration into the market. Furthermore, DVB signals are particularly well suited to be retransmitted over IP-based networks, thanks to their native packetized structure provided by the MPEG2 Transport Stream definition.

The paper is organized as follows: Section II provides an overview of HAN architectures appeared in the recent technical literature, to highlight differences and similarities with the proposed solution. Section III discusses the integrated HAN, and some results obtained through simulations. In Section IV a prototype set up is presented, together with evaluations and analyses of the performance obtainable in a heterogeneous scenario. Finally, Section V concludes the paper.

II. Proposed HAN Architectures

A survey of the most recent proposals presented in the technical literature about the implementation of Home Area Networks reveals a major interest in wireless solutions, based on standardized and well established technologies.

Khan *et al.* [12] propose the adoption of ZigBee as the communication technology for home area networks managed by a single coordinator, i.e. a single node able to command and monitor different devices, and to interface the indoor home network to the external internet. The adoption of ZigBee is mainly motivated by the availability of many different *intelligent* sensors, natively equipped by such a radio interface, that can support control of home facilities, security applications, and efficient energy management. Experimental results provided in the paper show that ZigBee allows a flexible hierarchical network modelling, with an optimized management for the reduction of the nodes' energy consumptions. With respect to this solution, the integrated HAN herein proposed is based on a hybrid architecture, that includes a number of ZigBee "isles", each located in a different room, and interconnected over a wired, Ethernet based, backbone. The hybrid approach provides higher reliability, thanks to the adoption of a stable backbone, and to the relative independence of each wireless subnetwork from all the others. If a single subnetwork is out of service, or affected by unacceptable impairments, all the others may still work properly. Besides that, the hybrid architecture allows a distributed management of the network elements: each subnetwork in a room has a local coordinator in charge of collecting and delivering traffic from the sensors and towards the actuators. Flexibility in the maintenance and development of the home network is also ensured by the possibility of adding or removing wireless subnetworks, without modifying the other network components. From the perspective of energy consumption optimization, the hybrid architecture enables a modular approach: different levels of energy saving and power supply guarantees may be configured for each single wireless subnetwork.

The HOMEPLANE project described in [13] aims to develop a homogeneous concept for the wireless integration of multimedia components in the home environment. Different devices located in different rooms are used to distribute multimedia services wirelessly, over an IEEE 802.11 independent basic service set spread within a house. However, when using standard off-the-shelf WLAN products, a critical condition arises, if multiple, high data-rate multimedia links operate simultaneously. The paper shows that by improving the efficiency of each link, through a cooperative concept, a good overall performance of the network can be achieved. The proposed architecture relies entirely on wireless solutions: IEEE 802.11 for high rate multimedia traffic delivery, and ZigBee for low rate network monitoring and control traffic. A modification to the standard IEEE 802.11 Medium Access Control (MAC) protocol is necessary, to support simultaneous multimedia sessions with given QoS requirements. The HOMEPLANE solution has a number of common features with the integrated HAN herein proposed. First of all, they share the common idea of providing a robust and efficient infrastructure for the delivery of multimedia traffic in the home scenario. The integrated HAN extends this concept by including also the delivery and management of home automation traffic. Most of the transport capacity required to deliver multimedia streams over the integrated HAN is provided by the Ethernet backbone, the presence of which simplifies the QoS management, with respect to the HOMEPLANE approach. The *wireless benefit* is partly lost, but the risk of congestion and packet dropping is also reduced. Besides that, the modular paradigm of several wireless "isles" connected over the wired backbone, simplifies the management of MAC-related issues (thanks to the limited number of devices included in the same subnetwork and subjected to the same traffic rules): traffic management rules are tailored to each subnetwork, thus avoiding the *flat* management otherwise faced by the HOMEPLANE proposal.

With respect to the Home Gateway Initiative [14], that is basically concerned with promoting the home technology market by specifying an advanced interface between the inner home environment and the outdoor internet, the proposed integrated architecture addresses the problem in a more global view, encompassing not only the home-to-WAN connection issue, but also all the issues related to handle and process the inner data flows, generated by either home automation and entertainment applications. The proposed HAN tries to provide an integrated environment without relying on a specific subset of consumer devices or appliances, unlike the Digital Living Network Alliance (DLNA) approach [15]. In comparison to the widely appreciated Universal Plug and Play (UPnP) solutions [16], aimed at connectivity between standalone devices and PCs from different vendors, the further requirement the proposed HAN tries to tackle is to ensure device connectivity even when advanced operations, typically supported by underlying Operating Systems on PC platforms, are not available. Finally, in [17], the authors present an integrated architecture for the server platform designed to control and manage the exchange of communications, broadcast transmissions, and automation data, within the home network. The proposed solution is completely integrated, meaning that a single box is equipped with different interfaces, cards, devices, and a powerful processor, in order to support all the data manipulation operations required. With respect to this proposal, the integrated HAN herein discussed is built upon separated servers, dedicated to different operations and services, such as communication (phone and cams data flow management), TV signals broadcasting, automation and management data flows exchange. This choice is motivated by the need of increasing the system reliability, by independently managing the different functionalities, and by the requirement of a low complexity and low cost implementation.

III. Simulation of an Integrated HAN

Before moving to a prototype implementation of the proposed integrated HAN and its network devices, a realistic scenario is defined and simulated, by means of the *Omnetpp* network simulator software tool [18], in order to test limits and performance of the proposed architecture. Due to the complex design of the different server nodes used to manage heterogeneous data flows within the HAN, a completely deployed architecture is not currently available. As a consequence, the results discussed in the following subsections are referred to simulated scenarios. On the other hand, a real implementation of the single nodes in the HAN, such as room control nodes, external and internal entry phone stations, and player devices to interface the HAN, is already available.

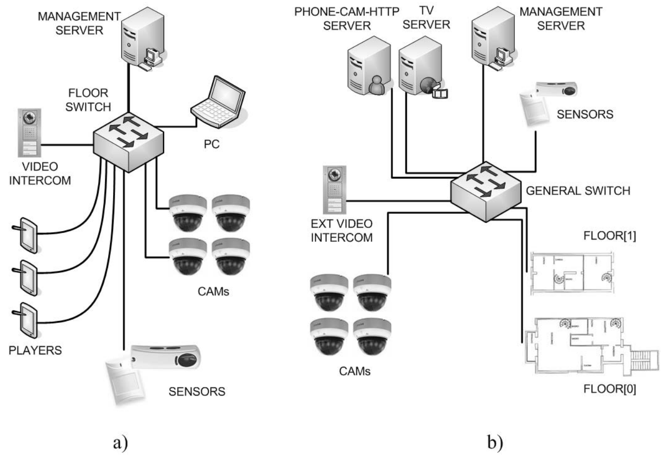

Fig. 1. The simulated home network: a) single floor elements, b) global HAN overview.

A. Simulation set up

First, the scenario of interest is defined. Aiming at developing a realistic model, we simulate a home automation system which serves two floors, each structured as a subnetwork including a floor switch, and a number of nodes connected to it. Such nodes represent different possible devices: players, sensors, surveillance cameras, PCs, and video intercom devices, as shown in Fig. 1 a). Players, in particular, have a basic role in the proposed architecture: they may serve as end devices for multimedia contents delivery (as an example, a player can deliver the audio/video signals coming from the external intercom device to the home user), and as terminals to handle home control data. They are called "players" as they actually do not perform decoding, in the case of multimedia signals, but they just deliver decoded streams to the user. The resource-consuming operations of decoding are left to the multimedia server included in the HAN.

Each element in a floor subnetwork model is simulated by implementing a properly modified version of the so-called Omnetpp *StandardHost* software component. In a *StandardHost* module, several sub modules may be placed, to simulate specific protocol stacks (such as the TCP/IP stack), network interfaces, and applications. For each *StandardHost* module, the simulator requires the definition of several parameters, such as the number of TCP applications, the number of UDP server or client applications, and the type of TCP applications to be executed. They are to be set according to the role of each node inside the simulated network. As an example, in the proposed simulation, the indoor intercom device runs a server UDP application and two client UDP applications: the former transfers voice signals from the inner to the outer intercom device, the latter are used to receive voice and video signals from the external device. Each surveillance camera has a single server application, to stream the captured video signal. Each multimedia player shall implement three client applications, to provide the TV, intercom, and surveillance video signals, respectively, to the user. PCs and sensors have similar models, based on a TCP application that simulates a web browser in the case of a PC, and a server engine in the case of a sensor, to push data over the network.

The links connecting each node to the floor switch are defined by three main parameters: *delay*, in seconds, *error*, i.e. the percent amount of error bits, and *datarate*, that can be set equal to 10 Mbps, 100 Mbps, or 1 Gbps, in the global configuration file. Assumed that no errors take place over the floor links, the parameter of interest is the *delay*, which is set to 50 ns (considering links of average length equal to 10 m). In each floor subnetwork model, the end devices are connected to a floor switch over Ethernet links. The global HAN model comprises two floor modules, and a number of adjunctive devices, as shown in Fig. 1 b). Each floor switch is connected to the general switch, that interfaces the management server, and the other servers included in the HAN. Among them, a TV server, a server to handle phones and videosurveillance cameras, and an HTTP server. The latter is used to simulate internet traffic exchanged with PCs, and to collect data originated by the sensors. In order to ensure a realistic behavior of the TV server, it is necessary to set a non-zero source jitter. By this way, the TV server generates data packets randomly, according to a normal distribution with standard deviation equal to the source jitter. At the receiving side, the total jitter is estimated by adding the network jitter to the source jitter. The last item necessary to run simulations is the so-called *Configurator*, a file that maintains IP addresses and routing tables related to the simulated scenario. At each simulation run, the *Configurator* assigns IP addresses to the nodes, discovers the network topology, and computes the shortest paths inside the network, by applying the Dijkstra algorithm; finally, the routing tables are set accordingly.

Two service scenarios, named *contexts*, have been simulated, the details of which are as follows:

SIMULATED CONTEXT #1:

- the HAN serves two floors, by a single main switch connected to the floor switches, over a 100 Mbps Ethernet infrastructure;
- besides the floor switches, an external intercom device, a TV server, a web/HTTP server, and four external cameras are connected to the main switch;
- a variable number of players, four cameras, a personal computer generating low traffic, and a single indoor intercom device are connected to each floor switch;
- the external intercom node generates a 1.5 Mbps video stream and a 64 kbps audio stream towards each internal intercom device;
- a single indoor intercom device sends a 64 kbps audio stream towards the outdoor device;

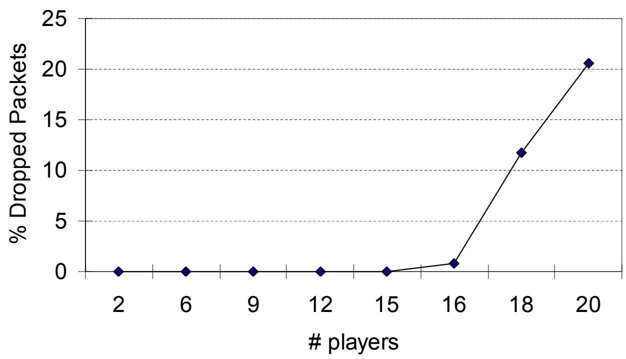

Fig. 2. Percent amount of dropped packets for different numbers of active players.

- a single camera at each floor sends a 1.5 Mbps video stream to the videosurveillance server;
- the TV server generates 6 Mbps Real Time Protocol video streams.

SIMULATED CONTEXT #2: The second simulated context features the above configuration, apart from the following changes:

- heavy HTTP traffic is generated by personal computers: they receive data from the HTTP server, at a rate of 0.8 Mbps, and send data at a rate of 10 kbps;
- a total of 12 sensors are added to the network (8 external sensors, and 2 indoor sensors, at each floor); each sensor sends a TCP packet of length 100 byte, per second, to the HTTP server.

B. Simulation results

A number of simulation runs have been executed, to obtain an average evaluation of the network performance, focusing on the percent amount of dropped packets and the average jitter. They are basically related to the transport of real time multimedia data on the network, and, in a prototype set up, they will be useful to test the expected performance of the video streaming service over the HAN, that is the most critical service from the user's perspective. For each run, 200 "real" seconds of network activities have been simulated.

As stated in the description of the simulated contexts, we assume the network infrastructure can provide a 100 Mbps transport capacity. Each TV server in the system is able to stream DVB-T channels in the MPEG2 Transport Stream (TS) packet format of 188 bytes (net RTP payload). The number of DVB-T channels that may be requested to stream at the same time depends on the number of active players; each player can receive a 6 Mbps DVB-T channel (we assume that 6 Mbps is the output bitrate of the DVB-T channel set by the broadcaster). Consequently, the net RTP bandwidth required for the delivery of DVB-T channels on the network is given by: (number of players) $\times$ 6 Mbps. The actual bandwidth needed is greater, because of the encapsulation headers added at each layer of the protocol architecture. As shown by the simulation results of Fig. 2, dropped packets appear only when the number of players active at the same time in the HAN is greater than 15, i.e. the required net RTP bandwidth is greater than 90 Mbps, a value that approaches the maximum transport capacity of the network infrastructure. Simulation of the second context shows that adding the transmission of sensor data does not affect the number of dropped packets, which exhibits minimal variations. The increasing number of DVB-T streams transmitted by the TV server to the active players reduces the capacity of the link between the TV server and the main switch, which is not interested by sensor data traffic. We can argue that packet losses are due to the multimedia traffic, which grows up to the amount saturating the available bandwidth in that link. On the other hand, as shown in Fig. 3, traffic due to sensors may affect the jitter performance, even if the degradation is not so evident, with a maximum increase of 0.5 ms for the highest number of active players.

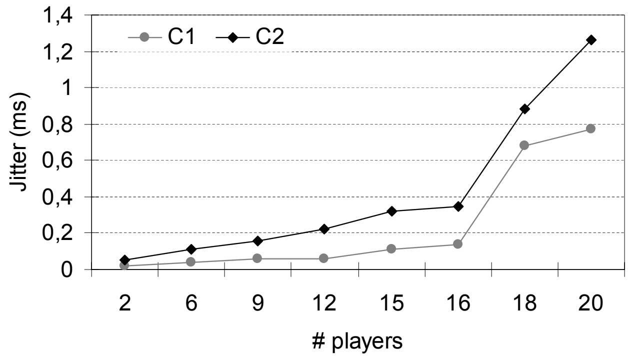

Fig. 3. Average jitter for different numbers of active players, in simulation context #1 (C1) and #2 (C2).

The results obtained through simulation show that, as expected, the multimedia traffic has a critical role within the network, due to its real time nature, and the possible saturation of the transport capacity, when many streams are to be provided at the same time. The capacity of the link connecting the TV server to the main switch should be estimated according with the expected number of simultaneously active players. Besides that, a suited topology should avoid the network overload due to multimedia traffic, by distributing data flows among the HAN switches. Packet losses caused by bandwidth saturation may then affect either multimedia and sensor traffic, which is a critical issue in any case: missing video packets may rapidly degrade the final quality delivered to the user, and missing sensor data may prevent from a correct management of the home facilities. To avoid these drawbacks, several solutions tailored to each specific case may be adopted: from a proper network design, to balance traffic among several switches and subdomains in the network, to the adoption of QoS rules, to the physical upgrade of the infrastucture, as required in the case of High Definition video delivery. For the home automation related traffic, acknowledgment mechanisms shall be implemented, to ensure the delivery of control and monitoring data, and to face possible packet losses.

IV. Prototype set-up and evaluations

A. System Devices

The prototype system architecture, based on the model described in the previous Section, has to fulfill two major requirements, i.e. the need for a high speed communication bus able to deliver high quality services, such as video entertainment, video intercom, and IP telephony, and the implementation of low cost local nodes, for sensoring and control execution. The former requirement is satisfied through the adoption of the Ethernet bus to interconnect the system control blocks. All the communication flows are directed towards the centralized HAN server through a five port switch, and the server may be remotely controlled and configured through a web interface. From a functional point of view, once complete, the system will include three sub systems: a room control node, a module handling room and external communications, and a module for the delivery of entertainment signals. In the overall architecture, players have a basic role. A player acts as the human/HAN interface: the user selects the desired content through a suitable menu, and the corresponding stream is transferred from the server to the player. To enable voice communications among rooms, and towards the external, an IP Telephony Server is implemented; all the rooms, if required, may also be equipped with an IP phone client.

The external video intercom is implemented by a device located outside the user's premise, and equipped with a videocamera and bidirectional audio channel. The device can communicate over the Ethernet link with an indoor, twin device, provided with an LCD monitor. The presence of this stand-alone receiver, usually located near the main entrance door, is typically required by the users, but, according with the proposed integrated architecture, any room device, equipped with a monitor, may interface the external video door phone, including a player.

Inside any room, a CAN bus is selected as the suited communication technology, thanks to the transfer rate it can support (that is enough to face the expected requirements), and the low cost of enabled nodes, due to the availability on the market of microcontrollers implementing the CAN protocol and physical interface. Any room board implements an Ethernet interface to communicate with the system server, and a CAN interface to monitor the local nodes. The local nodes provide room monitoring and command execution, such as presence monitoring and light switch on/off, but also external light intensity sensing, and internal light intensity variation. Temperature control, also possible, allows a more efficient management of the home heating plant, with a remarkable cost reduction. Aiming at making the whole system more robust against unexpected switches off of the room board, the network of local nodes can act as an independent network, being the in-the-room commands executed independently from the whole system.

Finally, the room boards are equipped with a wireless

Zigbee transceiver, to enable a remote control of the system functionalities by means of a commercial PDA. This is also configured as an IP wireless phone, to act as a remote control, and as a video interphone receiver, at the same time. Fig. 4 shows a block diagram of the integrated HAN system elements, and a picture of the prototype boards designed to implement the different modules. The communication flows among the system elements are evidenced in the block diagram. If the home automation data need not to be processed by the main server, they are handled by the room control board, and consequently they are not affected by external Ethernet traffic over the HAN. If, on the contrary, the home automation data are to be transferred to the centralized server, they are formatted for Ethernet transmission, and delivered through the main switch. Each room control board may connect to the centralized server over Ethernet links, as an example, for the delivery of entertainment services to the users located in that room.

B. System Services

Once the hardware elements of the system have been defined, it is necessary to ensure a correct and effective service provisioning. The proposed HAN relies on the LinuxMCE [19] client/server software platform, for the management of all the home entertainment and automation services: it integrates a media and entertainment sub-system for music, movies, and TV, a home automation sub-system to control lighting and household functionalities, a phone and video conferencing sub-system, a security sub-system with video surveillance, and a home PC solution. Digital television contents received from the external antenna are handled by the multimedia/TV server, and retransmitted over unicast links to the active players, on the basis of their requests. TCP connections are used for point-to-point streaming, to enable congestion control: by this way, QoS is mostly managed by differentiating the bandwidth allocated to the various streams.

The digital TV service has a medium priority assigned, with respect to the low priority of the Internet service, which reflects on different bandwidths allocated in normal conditions. Available bandwidths become variable during congestion events. The home automation traffic is assigned the highest priority (even if it requires the smallest bandwidth, with respect to the other services), and guaranteed the same bandwidth either in normal functioning and congestion, in order to ensure the availability of some basic home facilities, like safety and security systems. In the case of a congestion event, a TCP connection used by the TV streaming service may be released; the remaining active connections can exploit the additional bandwidth released, and improve their quality. On the contrary, the Internet service, of lowest priority, has an allocated bandwidth which is immediately reduced when congestion occurs, and may experience a substantial quality loss. Results about bandwidth allocation may be found in [20], [21], where the very preliminary design of the system elements is also presented. The solution herein discussed moves from that implementation, and provides further developments, in a more *network centric* perspective. The integrated management of multimedia and home automation data may be performed by acting on the two basic "levers" of bandwidth and priority. Services associated to the home automation system do not require significant bandwidth (they may be supported by a 500 kbps rate), but the reserved capacity shall be guaranteed even during congestion, and the related data packets processed with priority. Multimedia flows require the highest bandwidth, but this is not guaranteed during congestion events, so that the quality delivered to the user may suddenly degrade.

C. System Logic: Controls and Commands

Peripheral CAN nodes (sensors and actuators), located in each room, transfer their data over a CAN bus to the room control module, where a CAN/Ethernet interface is located. The CAN nodes are controlled by the exchange of specific commands, formatted according to an URL-like (Universal Resource Locator) syntax.

Commands may be issued by means of simple *http* requests, of the form: http://XNCPU:port/WorkingOut?rid=2&id=2&pin=1&func=160&time=0. The requested *http* resource identifies the command issued: in the example, the string *WorkingOut* is associated to the activation of a given load, controlled by a specific board (named XNCPU, in the example).

The other parameters appearing in the URL string are defined as follows: 1) *rid* (requestID), is a counter used to associate each request from a client to the corresponding response from the system; 2) *id*, represents the MAC address of the board which activates the given load; 3) *pin*, locates the actuator to be activated, among those controlled by the same board; 4) *func* is a three-valued parameter (0 = off, 255 = on, 160 = Toggle command); 5) *time*, denotes the time validity of the command issued (time = 0 means immediate execution of the command).

Other available commands (almost 30 different commands are defined to manage the system) deal with initial system configuration, message broadcasting, polling of actuators, sensor data collection. The definition of the commands follows a hierarchical association between the CAN bus primitives, the location of the sensors within the home environment, and the corresponding *http* requests. By this way, the valid *http* requests may be defined once the system topology has been deployed. The adoption of *http* requests and responses to manage the home automation system allows a modular evolution of the system itself, so that future developments will enable the remote management of the home plants through a web interface accessible from anywhere, over an Internet connection. As an example, if the user presses a button located on the HAN user interface corresponding to light control in the dining room, the underlying logic will compose the corresponding *http* request by properly setting the required parameters (e.g. the MAC address of the board in the dining room, which will activate the given load, or the *pin* necessary to locate the actuator to be activated). Once complete, each *http* request is sent over the home data network. The following code extract describes the *sockaddr_in* data structure, which includes either the IP address and the protocol port number:

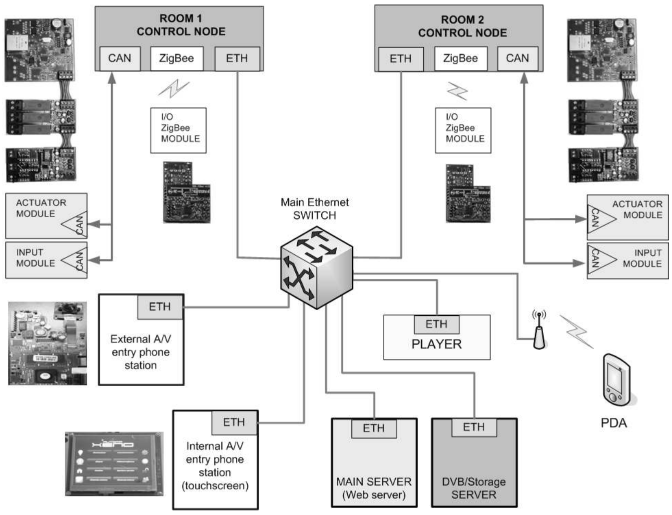

Fig. 4. Block diagram of the integrated HAN system elements, and corresponding data flows.

```
struct sockaddr_in {
short sin_family;
u_short sin_port;
u_long sin_addr;
};
```

where the type of address, protocol port number, and net address of the remote device, respectively, are declared.

V. Conclusion

The Internet Protocol paradigm has become the leading solution not only in general purpose communication and data networks, but also in Home Area Networks intended for home entertainment and automation. In this paper we presented an IP based integrated solution for Home Area Networks aimed at unifying the management of different data (multimedia and home automation), services, and devices (servers, personal computers, sensors and actuators). Given the home scenario of interest, digital television services play a prominent role and must be properly delivered, even if they coexist and share network resources with phone, video surveillance, automation, and Internet traffics. The introduction of a Quality of Service enabled router in the home network architecture should be recommended, as it permits to effectively regulate the priority and bandwidth assigned to each service, through the definition of proper rules. They are fundamental in avoiding bottlenecks and ensuring continuous availability of the basic, and essential, home appliances' functionalities. Future activities in this field are related to the detailed definition of a homogeneous Quality of Service paradigm for the integrated management of multimedia and home automation data, in such a way as to define a set of configurations, and test them in a real implementation, to enforce the validity of the proposed solution. Further analyses will focus on reliability tests, in order to verify the proper reaction of the system to congestion events or malfunctionings that may compromise basic home appliances. Other multimedia services, besides the DVB-T one considered in this paper, shall be introduced in the system, in order to come to a complete solution for joint home automation and entertainment data delivery. A basic important issue to tackle in future developments deals with proper strategies and protocols to ensure the security of the communications among the network nodes, and the security of the HAN with respect to external accesses.

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Susanna Spinsante received her Laurea degree (summa cum laude) in Electronic Engineering in 2002 from the Universit di Ancona, Italy and, in 2005, the PhD in Electronic Engineering and Telecommunications at the Universit Politecnica delle Marche. Her main research interests are related to security and encryption aspects in communication networks, multimedia applications over IP, coding and audio/video applications. She is a member of IEEE.

was born in Ancona, Italy in 1961. He received his Laurea degree in Electronic Engineering from the Universit di Ancona, Italy, in 1986. In 1992 he joined, as a researcher, the Dipartimento di Elettronica ed Automatica of the Universit di Ancona, where he is currently the lecturer for the course of Telecommunication Systems. He is presently working on radio communication systems, multiple access techniques, video signal processing.