DomoBus - A New Approach to Home Automation

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Abstract

This paper describes a home automation system - the DomoBus - that was developed as an academic project. The architecture of the DomoBus is detailed and we describe the options taken in order to achieve a system simple and cost effective, but also powerful and easily expandable. The DomoBus has a distributed architecture but each module controls multiple devices (sensors and actuators) to optimize the hardware resources of each module. This approach has several benefits and we compare it with current solutions. One of the objectives of the DomoBus is to address "super-automated" homes, i.e. homes with a very big number of control points and with a rich set of integrated services. We focus also on aspects of system installation and we describe an approach to system supervision, based on scenarios, which allow the users to configure and adapt the system to their needs and preferences.

Keywords: Home Automation, Home Networks, System architecture, System Installation, Super-Automated Homes.

1. Introduction

Home Automation offers many benefits and its awareness and usage has been steadily expanding. Although its global market value is still very low, we observe an increasing number of companies being active in this field, offering a diverse range of products. The home automation expansion is being helped by the massive spread of the Internet at home and new technologic developments in cable and wireless communications and mobile computing.

Home automation main benefits regard increased comfort in the home, more safety and security and better energy management. In this last domain, many possibilities exist. It is feasible to implement policies to reduce energy consumption and to reduce its cost (transferring consumption to "off-peak" hours, for example). It is also possible to use more rationally different forms of energy (e.g., electricity and gas) and other fundamental resources such as potable water. And home automation can also play an important role in a more effective use of renewable sources of energy, namely solar water heating panels and photovoltaic cells.

The evolution of home automation has been difficult. After an initial period dominated by proprietary products, some standardization movements were initiated. The objective was to allow compatibility between products of different companies and promote cost reductions, increase product diversity and foster a more rapid market expansion. At the end of the nineties several international standards were available (namely, CEBus [2] and LonWorks [3]). Some companies also took the initiative of forming associations, freely accessible, and disclosed the full specifications of their products to its members (for example, EIB [4]). However, the anticipated results did not materialize. The existence of various standards divided and confused the market, and new products and technologies kept appearing. Recently, in an attempt to gain market with low cost solutions, some companies went back to proprietary technologies, using simpler products, with fewer features and cheaper. This can be criticized but has the benefit of contributing to the awareness and spread of home automation.

This paper describes a home automation system - the DomoBus - that was developed as an academic project. Its development was carried in order to overcome many difficulties felt while trying to access standard products for testing and experimentation purposes. Implementation of standard products also revealed difficult. Frequently, special development tools were needed or specific integrated circuits and other components, which were not easily available. This led to the development of the DomoBus system, which has been used as a learning tool and as a test bed for new ideas and applications.

In the next section we present an overview of the DomoBus, describing its architecture, its constituent modules and their functions. We compare our approach with current solutions and describe its advantages regarding the ability to implement complex solutions in a cost-effective way. We focus also on the ability to interconnect with other networks, to promote interoperation and accomplish an integrated solution.

Next we detail the concept of super-automated homes and exemplify what type of functions are desired and how big the number of control points can reach, even for a medium size home. We address system installation issues and emphasize how the DomoBus architecture offers benefits over other solutions, as a small number of modules can be easily installed in each room of a house, simplifying cabling to sensors and actuators, and making installations more modular.

Finally we tackle system supervision presenting a distributed approach where multiple Supervision Modules can coexist, allowing, for example, each room to be managed by a different module, with benefits regarding load share, responsiveness and reliability.

We present also a simple model for the users to program the house behavior that is based on the notion of scenarios.

2. DomoBus overview

The architecture of the DomoBus is illustrated in figure 1. A DomoBus system is composed, essentially, by Control Modules (CM) and Supervision Modules (SM), which are interconnected by a communication network that allow them to interact and cooperate with each other.

The Control Modules are small microprocessor-based boards that connect directly to switches, temperature sensors, infrared receivers and other input devices. And they can control power electronics used, for example, to adjust the intensity of lights or to turn on/off small motors, pumps, lights, electric heaters or air conditioners. They can also execute other types of specialized actions, such as the generation of infrared signals used to command TVs, HI-FIs or other consumer electronics equipment.

Current CM prototypes are quite flexible. They use a microcontroller that includes code and data memories and various peripherals for timing purposes and for communication. Each CM includes also a communication transceiver (EIA-485) and interfaces for reading switches and other input devices, and commanding of the needed power electronics. A more detailed description of a CM prototype can be found in [6].

Each CM is able to run different applications and perform different functions. For example, a CM may read 8 switches and control the intensity of 4 light channels, while another CM may read and emit infrared signals and control 8 relays. This ability clearly distinguishes the DomoBus from other solutions such as X10, CEBus, LonWorks and EIB. In these technologies, commonly, a module controls just one device. The DomoBus approach can thus be much more economical as the hardware resources of a CM allow control of multiple devices (up to 20 in our prototypes), making it feasible and cost-effective to address super-automated homes.

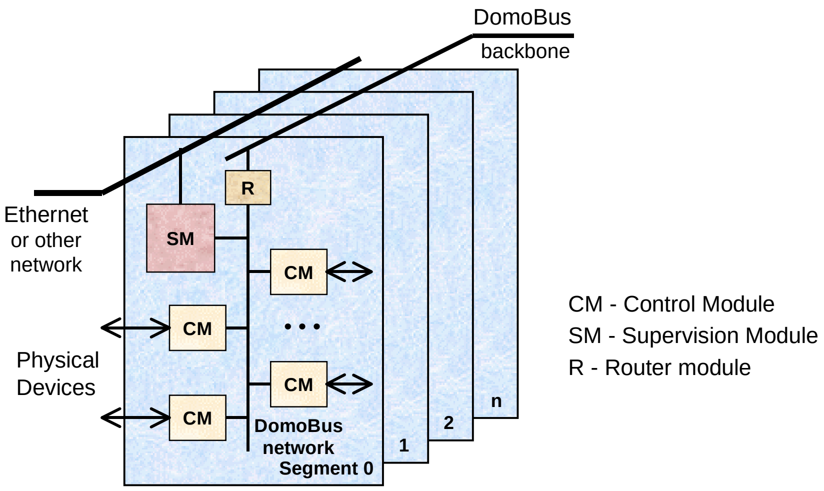

Fig.1 - Architecture of the DomoBus system

Another important aspect regards the devices themselves. While an EIB switch, for example, is a self-contained module that incorporates a microcontroller, associated peripherals, power supply, communication hardware, and the physical switch itself, the DomoBus uses a CM located in a technical panel (probably together with other CMs) and employs an ordinary electric switch. This approach, allowing the usage of commonly available switches and power sockets, is cheaper and offers much more freedom regarding aesthetics and other aspects.

To simplify the expansion of the system, the DomoBus network can be decomposed into several segments. In this case, inter-segment communication is achieved using a backbone segment and routing modules (R) - see figure 1. This approach allows an increase in the overall communication traffic, as communication within one segment does not affect other segments.

The Supervision Modules (SM) are responsible for system management and supervision. They receive information from the CMs, process it accordingly to programmed rules and required behavior, and issue the appropriate commands to the CMs. A system may have as many SMs as needed. In a small system we can have just one SM, while in a big or complex system we may have, for example, one SM for each DomoBus network segment, as illustrated in figure 1. In this way, events generated by CMs connected to a given network segment can be received and processed directly by the associated SM. This approach allows a distributed supervision, offering benefits regarding response time and reliability (no single points of failure).

Note that a SM can control any CM in the system and that the SMs can interact with each other in order to share information or coordinate actions. To that end, the SMs can use a different network (for example, Ethernet or a wireless LAN) with more bandwidth and support for multimedia services. In this way, the interaction with other systems also becomes easier allowing interoperation and achievement of integrated solutions.

In the proposed architecture we consider the existence of a PC - the Home Server and Gateway (see figure 2), that offers a powerful graphical interface with the user for system monitoring and programming. The Home Server and Gateway allows access to the Internet and may also interact with other systems if required.
The system supervision actions are defined and managed in the Home Server and Gateway. However, those actions are downloaded to the Supervision Modules, which carry on the programmed tasks. In this way the PC can be turned off without disturbing the system's control and automation functions.

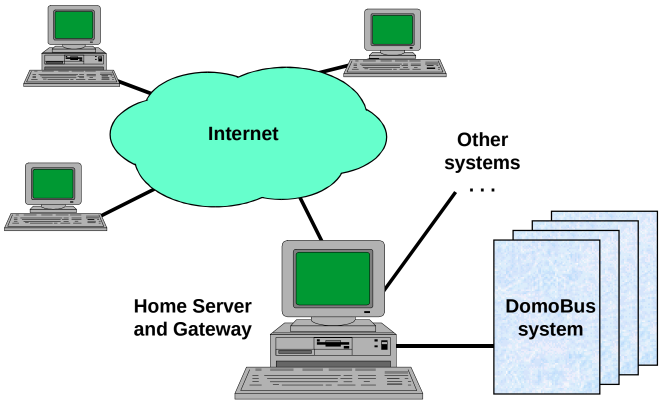

Fig.2 - Interaction with other systems and support for remote access

3. The concept of "super-automated" homes

Current home automation solutions involve, typically, a small number of control points. In a T3 type of home, with one living room, one kitchen, three bedrooms and two bathrooms, one may expect (in an already highly automated home) around 35 control points. These may correspond, for example, to 8 lights, 10 switches, 5 temperature sensors, 5 heater controls, 7 presence detectors (for lighting control and intrusion detection), and one RF remote control. Although this is a high number compared to common basic automation solutions, we want to address a much bigger number of control points and offer automation levels an order of magnitude greater. Given our aim, we introduce the concept of "super-automated" homes that apply to homes with a very big number of control points and a rich set of integrated services.
To illustrate the level of automation envisaged, we detail what could be expected in a single room of such a home:

- 3 lights (ceiling/lamps, all with intensity control);
- 3 switches to control the lights (short pulse: on/off; long pulse: control intensity);
- 2 outputs for moving up and down the window blinds;
- 2 switches to control the window's blinds (up/down);
- 2 on/off sensors to monitor the open/close status of the window's blinds;
- 3 outputs to control electric power sockets;
- 1 presence sensor;
- 2 on/off sensors to monitor the open/close status of the room's door and window;
- 1 temperature sensor;
- 1 smoke sensor;
- 1 light intensity sensor;
- 3 switches to control the ambience sound (one for channel and two for volume);

- 1 infrared remote control receiver (to issue commands to the automation system);
- 1 infrared remote control emitter (to command a TV, HI-FI or other equipment);
- 2 switches to select usage scenarios;
- 4 low power outputs to signal specific status/operation conditions.

The example just presented accounts for 32 control points. Considering that a house has simpler divisions (such as the bathrooms), but the kitchen and the living room are more complex, we can estimate that, for the T3 type of home referred earlier (with 7 divisions), we will have more than 220 control points. This number will increase significantly for a detached house, which will be bigger and have, probably, a garden and outside equipment. This clearly represents a different approach to home automation and the DomoBus offers a solution to it.

4. System installation

In the case of a "super-automated" home, and in order to simply the system physical installation, we propose an approach that uses a technical panel in each room, where two or three CMs are installed to control the devices in that room.
A room receives electric energy in its technical panel, which includes the required protection elements, and connects to the DomoBus network. Power distribution in the room (to lights, power sockets, window blinds motors, air-conditioner and other devices) is controlled directly by the CM modules that also read switches, sensors and other input devices. This simplifies the physical installation and makes it more modular.
Physical devices need to be installed and connected to the technical panel using suitable electrical cables. In some cases, where several switches or other devices lay in close vicinity, multi-wire cable may be used, reducing the cable raceways in the walls, ceiling or floor. Note also that some sensors may share a common enclosure (for example, the presence sensor and the infrared remote control receiver; the smoke, temperature and light intensity sensors, etc) and that, depending on the location of the technical panel, some sensors may be installed directly in it. This further simplifies physical installation and contributes to the feasibility of "super-automated" homes.
We reiterate that, with our approach, common electric switches and power sockets (besides other electric boxes and faceplates) may be used, with advantages regarding cost and, eventually, aesthetics.
Our proposal is particularly appropriate to new houses, but it offers also advantages regarding already built houses in which the owner intents to make major renovations and add home automation. This is true as it allows confining many interventions to each room (or adjacent rooms), allows usage of small technical panels/enclosures, and reduces the number and length of cables and respective raceways, particularly when compared to centralized solutions. The various technical panels will be interconnected for power distribution and for communication between the DomoBus modules.
To conclude this section we make some remarks regarding power-line and wireless communication technologies. These can be the only solution in already built houses if automation features are required and no renovations are intended. However, in many situations, the possibilities can be quite limited. For example, actuation will be possible only at available power sockets, which can be fewer than required and have restrictions in terms of power. Regarding sensors, wireless technology can offer many advantages - sensors can be easily installed (glued) where needed, without the need to use any cables. However, besides possible problems regarding electromagnetic interference (to which power-line communication is also quite sensitive), we should stress that those devices

are powered by batteries that will have to be replaced regularly (once a year, for example). This is often forgot but can be quite inconvenient and have a significant ecological and economical impact.

5. System supervision

The DomoBus offers a simple model for the users to program the house behavior, which is based on the notion of scenarios. The user is able to create, modify or delete scenarios which are basically a set of conditions that, when met, originate a set of actions to take place. As an example, one may define scenarios corresponding to "go to bed and secure the house", "wake up in the morning", "arrive from work", "watch TV", "weekend - simulate presence", etc. Scenarios are defined in the Home Server and Gateway PC, downloaded to the SMs and executed there. This approach allows the PC to be turned off without affecting the control and automation tasks. The SMs receive information from the CMs, test if conditions are met and, if affirmative, send orders to be executed.
A DomoBus system may have any number of SMs, from just one for the whole house, up to one for each room. The choice depends on the size of the system and on the number and complexity of the required scenarios. A decentralized approach offers benefits regarding load share and system responsiveness, and also better reliability as single points of failure are avoided. If a problem arises in a module, it may affect one room, but the rest of the house will keep performing their tasks.

6. Conclusion

In this paper we presented the home automation system DomoBus. We described its architecture and emphasized the fact that it has a distributed nature, although each control module is able to command several devices. This makes the overall system more cost effective and makes it feasible to address homes with a very big number of control points, i.e., super-automated homes. This concept was presented and we described an example of the control points that could exist in a room. We also tackled aspects of system physical installation and how the DomoBus architecture may be used to simplify and make more modular the cabling to sensors and actuators. Finally we briefly described an approach to system supervision where the user is able to define scenarios that are used to control the behavior of a home.

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