Technology review: remote controlled home environment

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Introduction

For the experiment "focus management and service awareness in ubiqioutous computing environments", to be run at TNO, we would like to be able to control the environment of the user remotely, such that the user gets an impression of real working agents. Here we review a number of simple solutions for remote controlling (RC) a home environment.

Unfortunately, a huge amounts of "standards" has been proposed for home automation. A big overview is availale from the hometoys officeautomation page [hometoys] and by Ido Bartana [Bartana03]. Some are independent of the carrier, other standards are specific for one (twisted pair, radio, IEEE 1394, powerline, infrared, etc).
Discussion of all these systems is largely outside the scope of this report. We will discuss a few systems that are cheap and easily available in the Netherlands: X10 and a few radio controlled (non-standard) systems. We find that the cheap RF controlled systems are good foru our experiment, but lack two-way communication that is needed on the longer term. X10 is better in this respect, however it has a very low bitrate resulting in long latencies. The system at the homelab of Industrial Design Engineering at Delft University built their own custom solution, which we discuss shortly. However this sytem requires extensive cabling. Finally we shortly discuss the lonmark system, a professional system.

Radio controlled systems

Gamma [Gamma], Praxis [Praxis] and Conrad all sell relatively cheap products. These are all completely radio controlled. It seems that none of these numerous radio controlled systems is compatible with another.
Praxis sells the AB600 wireless home automation system from Elro [ELRO]. Their RC works at 433MHz and has a range of 30-50m. To give some prices, they have an RC plus 3 power sockets for € 52 (1.7A, 400W), a wall-switch look transmitter is € 20 (Figure 2), an inbouwdimmer €25 (as Figure 1, 250W) and an inbouwschakelaar € 19 (Figure 1, 1000W). They have a 16 channel remote control, with 8 control buttons to directly control 4 channels for up and down, and a switch to select channel 1-4, 5-8, 9-12, and 13-16.
Gamma has the "klik aan klik uit" system [Gamma03]. They have an amazing collection of RC door bells apparently to make an alarm system, but besides that they also have RC control units, a motion sensor, an inbouwschakelaar € 20 (1000W, also available in 3500W), inbouwdimmer (€ 25) (similar to Figure 1), wall switch (€ 20, looking similar to Figure 2 but without the LED), a set with 2 power sockets and an RC controller (€ 53, 3500W), a set with 2 dimmers and an RC controller (€ 55, 400W). They also have an

8A switch to control blinder motors (€ 35, 1000W, or max 4A with 48V according to manual, but the box says max 8A at 220V!). Their transmitter has a range of about 30m indoors (75m outdoors), and has 256 channels.

Figure 1. Praxis/X10 Inbouwschakelaar and inbouwdimmer.

Figure 2. Praxis RC switch (transmitter).

Figure 3. Praxis RC.

Figure 4. Praxis power socket.

Conrad also sells completely radio-controlled systems. Their system works at 433.92MHz, and has a range indoors 25 m. They have a dimmer (Figure 5, € 26.50, 300W, 100W with halogen), a normal switch box looking similar (€ 16.50, 3600W), a ceiling light switch (Figure 6, € 33, glow bulb 300W), a set with 4 3600W switches and two transmitters (€ 62), a 3 channel receiver print for do-it-yourself construction (€ 69), a light switch transmitter (Figure 7, range 5m for dimming, 20m for switching, € 30), a power socket with built-in timer (Figure 8, €24, 3680W), a thermo-set with adjustable target temperature and time (Figure 9, € 48, 3600W), a 6-socket box with 5 switchable sockets (Figure 10, €62, 3600W total).
Their radio system is a bit confusing. For switches (power sockets, lights etc) they use 434MHz. They have 10 bits to address switching devices, allowing up to 1024 channels.

However, for their dimmers they use 868.35MHz, and apparently a different protocol. Apparently you need different RCs to control the normal lights and the dimmers.

Figure 5. Conrad 300W (100W halogen) dimmer.

Figure 6. Ceiling light bulb switch, 300W.

Figure 7. Light switch transmitter.

Figure 8. Power socket, 3680W.

Figure 9. Thermo set

Figure 10. 6-socket box.

Conrad separately sells driving systems to open garage doors, and window shutters, we might be able to use these to open or close the luxaflex (Figure 11, € 125,. 10Nm). We probably can use standard receivers (e.g., an 8A switch) to steer the motor.

Figure 11. "buismotor" for opening window shutters.

X10

Worldwide, X10 [X10] seems the de-facto standard for home automation. Quite a lot of manufacturers make X10 compatible products, making a large collection of equipment for lots of applications.

X10 technically works by sending control signals over the 220V powerlines, as 120kHz pulses of 1ms duration on top of the mains power (Figure 12). A "1" is encoded as a pulse on the upgoing 220V flank followed by no pulse on the downgoing flank; a "0" is encoded as no pulse on upgoing and a pulse on the downgoing flank; and a special "start code" is encoded as three pulses on subsequent up,down, and upgoing flank followed by no pulse on the downgoing flank.
To command a device, we need to send an address followed by an instruction. Roughly, address consists of a start pulse, an 8-bit address (four "letter" bits and four "number" bits) and a "0" (the last 0 means it's an address). An instruction code contains a start pulse, a 4 bit letter code and a 4 bit command code, followed by a "1". So we have 11 bits for both address and instruction. Now every command is send twice to increase chances it arrives, and between address and command there have to be 6 zero crossings without any data at all. Finally, before a command is send the sender has to listen to the powerline and can send only after 8 to 10 empty cycles passed. This makes a total of 57 cycles for a single command, or more than a second! For some special commands as "all lights on" no address is needed, making it faster. More details are in [Kingery99]. With a two-way X10 protocol this will be even slower.

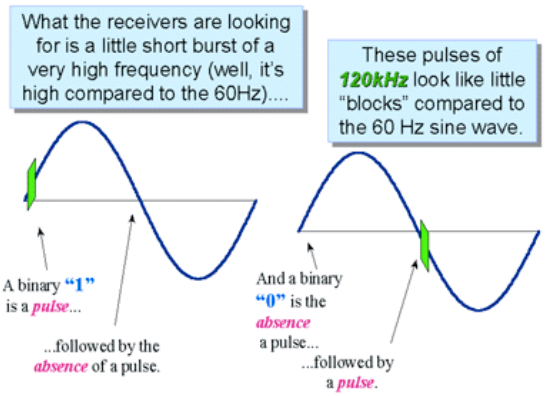

Figure 12a. X10 encoding of "0" and "1" on top of the 50Hz/220V or 60Hz/110V mains power.

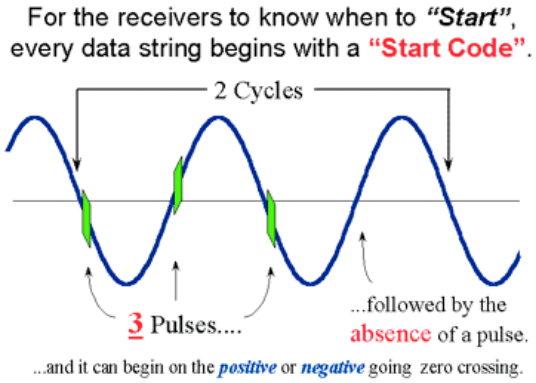

Figure 12b. encoding of "start".

Not only the remote controls can inject signals onto the mains power, but also for instance video cameras, motion sensors, computers etc. A computer can then be used to control the whole system. X10 can also be controlled via radio or infrared, a special converter box (usually incorporated in a switch or dimmer module) is needed then.

An advantage of X10 over the cheap radio controlled solutions is that all X10 compliant devices should be all compatible. X10 has a long tradition and components should be compatible (although I have nowhere seen this stated explicitly), which brings a huge amount of devices, switch types etc into view and offers a better prospect to future re-use and extension of the system. The cheap systems are all incompatible, the only components available are those that we find in the shop, and if we need something else we'll have to make it ourselves which probably is prohibitly expensive.
Another important advantage is that the X10 protocol allows readout of the status of devices. When multiple agents can independently access a device, or when fully automated control is required, it is essential that agents can not only attempt to set a device but also check its status. This is not possible with the cheap radio-controlled systems we checked.
In the Netherlands, X10 systems are sold by various companies, for instance Conrad [Conrad] selling Marmitek components [Marmitek], DIL [DIL] and Xanura [xanura]. Most companies offer only a fraction of the available products, for instance Conrad seems to sell mainly RC controlled components but hardly any powerline controlled components.
To give some price impressions, from Conrad: an inbouwdimmer (€ 75, 700W), a rail switch to control spot lights (Figure 13, € 63, 16A), a light bulb fitting switch (Figure 14, € 30) and a power socket (Figure 15, € 40, 3600W).

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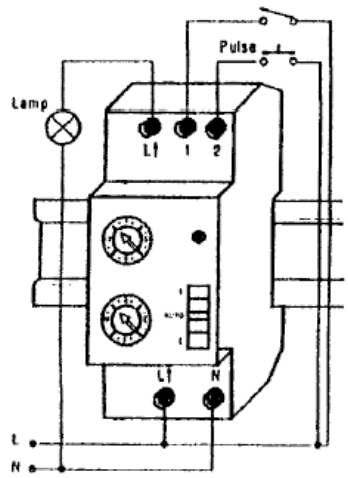
<td> 
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<td>Figure 13. rail spot controller.</td>
<td>Figure 14: light bulb switch</td>
<td>Figure 15. Power socket.</td>
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Other components available from Marmitek are a wireless thermostat, motion sensor, superflat 4-switch panel, dimmer of 300W, a 1000W power socket with built-in transceiver that puts RC signals, inbouw dimmers with switch (60 - 500W), inbouw switches (Figure 16, 2200W), phase filters to prevent X10 signals from outside the building coming in and inside signals from going out, etc. They also have micromodules, to build into an apparatus instead of onto the wall.

Figure 16. inbouwswitch.

Figure 17. motorized drape controller.

But many more X10 controllers are available, for instance from SmartHome [smarthome]. Interesting are their motorized drape controller (Figure 17, $89), their automatic pet doors and their "HAL" control your home by phone via voice ($240). Their HAL system is impressive, for instance it can handle requests like "every monday and friday at 7:30 AM, turn on the living room fan for thirty seconds". When access to the internet is available you can also ask information, for instance "What is today's baseball schedule for New York Yankees?". or "What is the news on Intel". Direct addressing of X10 devices is also possible, for instance "turn A3 on". Most of these are 110V devices but conversion to 220V apparently is not too difficult in most cases [Bartana03]
As said, the bitrate is very low and consequently there is a substantial delay, in practice the order of 1 to 3 seconds, between the moment a button is pressed and the moment the device reacts. Especially for light dimmers this is very confusing for a user who looks at the light while turning the knob to get the right intensity, but when entering a room one also expects instantaneous switching instead of having to wait a few seconds.

IO Homelab

The Inteligent Products Group at Delft University of Technology recently opened their home lab. They had troubles with the substantial latencies in the X10 system, and decided to build their own custom solution. They took the quick-and-dirty approach. They used turning knobs without center point for dimmer switches. These knobs were connected to a midi interface to get their signals into a computer. The computer then generates RS232 signals that are send to custom-made dimmer boxes that create a 220V dimmed power supply for the lights. So all dimmers and lights are hard-wired to the computer. Custom made programs are used to make up the user interface and device interfaces. This creates a fast system but highly inflexible and requiring a huge amount of wiring. Therefore I don't think this is suited for our experimental setup.

LonWorks

Echelon has designed a professional remote control communication protocol named LonWorks [Echelon03]. The protocol can use powerlines, twisted pair cable or existing IP networks. There are hubs available that can connect those mediums. It has a TCP like addressing structure, with an 48 bits physical address that is abstracted with a device address, group address, and broadcast address. Automatic acknowledging is possible, confirming receipt of a package. Each domain can have up to 32385 devices. There can be 256 groups, with 64 devices per group if ACKs are needed. Datarates are 5.4kbps over powerline, 78kbps up to 1.25Mbps over twisted pair, and higher with an IP network.
There is a huge collection of devices available, a central search engine for LonWork compatible devices is at lonmark.org. Many industrial devices are available, such as boiler controllers, ceiling chiller controllers, fan controllers, thermostats, temperature sensors, building management controllers, air handling control, heat pumps, fire detectors, energy meters, CO_2 sensors, and many other devices. It's hard to find wall switches in the huge collection, but they are there (Figure 18-20). Most actuators are industrial build-in or rail type boxes. I did not yet see prices but probably these are more expensive than the other solutions.
The LonWorks solution may be particularly interesting for TNO because TNO-FEL in the Hague has already used it before [TNO-LON99]. They controlled sunblind controllers with sunsensors and group control switches at the front door office.

Figure 18. LonMark compatible switch module (Samsung iBAS).

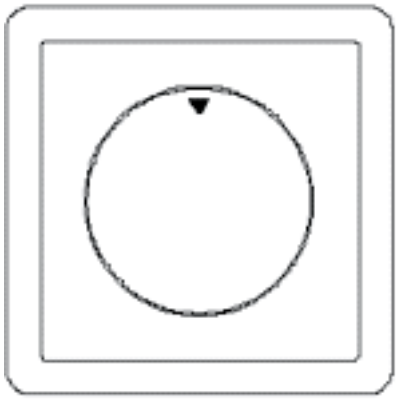

Figure 19. Lexel (Ahlstrom) pushbutton unit.

Figure 20. Siemens room controller with 3 light- and 3 blind switches.

Other alternatives

There are several other alternatives but currently we lack the time to investigate them further. Most companies are not very generous with technical specifications, protocols etc, making it hard to find a good system for our purposes.

Conclusions

Praxis, gamma and other dutch stores sell cheap devices to remotely control electric equipment. These devices are probably sufficient for our experiment. However these devices do not give feedback, making them less suited in a fully automated environment.
X10 is a relatively cheap and standard solution that has such feedback. Devices are two to three times as expensive as the cheap RC solutions. However X10 is very slow, and in combination with dimmers people reported it being too slow in fact.
LonWorks is a professional solution, provides two-way communication if needed. I have not seen any prices yet.
For our experiment, we probably can get quite far with a gamma, praxis or conrad system, also because the experiment controller can visually check the status of the controlled devices via the video cameras, re-pressing the controls on the RC until they work as required. Furthermore, we don't need a very professional looking system, a few loose wires are probably not a problem although a loose motor for controlling the blinds is a border case. But for future compatibility and especially to enable readout of the status of devices, I think TNO should invest something extra. X10 seems somewhat limited, if they can afford it LonWorks seems best solution.

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