HOME AUTOMATION CODE CAMP 2018

Group 6 :

Severi Ahopelto, Hannes Hietanen, Anisul Islam

Contents

Idea and motivation

Modern classrooms use many kinds of technology and equipment: computers, monitors, TVs, projectors, printers, etc. These devices consume some power when plugged into an outlet even when they are turned off. The consumption of an individual device is very low, but when you consider that LUT, and schools in general, have hundreds of computers and other devices which are not in use most of the time, for example at night or on holidays, it adds up to significant amounts. Eliminating this unnecessary consumption could save a lot of money.

We will try to solve this problem with our automated system which completely shuts down the power in a classroom when it is not in use. We implemented a much simpler version of this system, by using basic home automation power meters and switches to control the power for a single computer and a light bulb.

The main motivations for this project are the energy savings, but the increased comfort from the automation of some things, such as lighting or heating, is a good benefit as well.

Vision

Our vision is a classroom with no power usage when it is not in use. In addition to the implemented features, we also thought about how this system could be improved in the future. We focused on the possibilities in 5-10 years, although some these things might be partly possible to implement even today or in the near future.

Smart windows

Automatic dimming of windows could be useful to control the amount of sunlight in the classroom. This could work together with the lighting, since the brightness of the lights can be lowered when there is a lot of natural light available from outside. The windows can be dimmed completely in situations where the classroom needs to be very dark or direct sunlight is distracting. Smart windows could also generate some power from the sunlight.

Smart walls

Smart walls can detect people inside the room more accurately than simple motion sensors. The walls could also be used as an interactive surface when necessary. The interactions could possibly be based on either touch or gestures. There would also be no need wall switches since the interactions could be done on the interactive wall.

Smart heating

Heating could be automated based on the classroom schedule. This way the classroom could be already automatically heated in the morning when the first lecture starts and the heating can be turned down or off to save energy after the last lecture in the evening.

Implementation

We tried to implement a smaller portion of our vision. The implemented part were:

1) Idle power consumption cutoff
2) Situational Lighting

Tools

We used Fhem which is a Perl based home automation server. We connected two HomeMatic device: Homematic Power Meter, Switch and Motion Sensor for implementation. We can list down the tools as below:

- DHCP server
- Fhem server
- Homematic Power Meter
- Homematic Switch
- Homematic Motion Sensor

Scenario

Fhem server were assigned IP dynamically from our DHCP server. For our first implementation, we paired the motion sensor and power meter to our Fhem server. We were monitoring the energy consumption in power meter and motion sensor. Through which we're detecting the idle and active state inside the classroom and taking action accordingly. If it's in idle state, we power off the meter.

For second implementation we paired two Homematic switch. We assumed to one of the two switches Beamer/Projector is connected. We the Beamer/Projector is on, we're turning off the other switch, to which we assume lightings are connected.

Code snippet of our implementation is given below:

```
HM_3F889B {
    my $beamerStatus = ReadingsVal( "HM_3F889B", "state", 0 );
    if   ( $beamerStatus eq "on" ) { fhem "set HM_2C111D_Sw off"; }
    else                   { fhem "set HM_2C111D_Sw on"; }
}

HM_3E6A69 {
    my $motionSensorStatus = ReadingsVal( "HM_3E6A69",        "state", 0 );
    my $switchPowerConsumption = ReadingsVal( "HM_2C10FE_SenPwr", "state", 0 );
    if ( $motionSensorStatus eq "motion" ) { fhem "set HM_2C10FE_Sw on"; }
    elsif ( $motionSensorStatus eq "noMotion" && $switchPowerConsumption < 5 ) { fhem "set HM_2C10FE_Sw off"; }
}
```

Figure: Code snippet of implementation.

Design Diagram

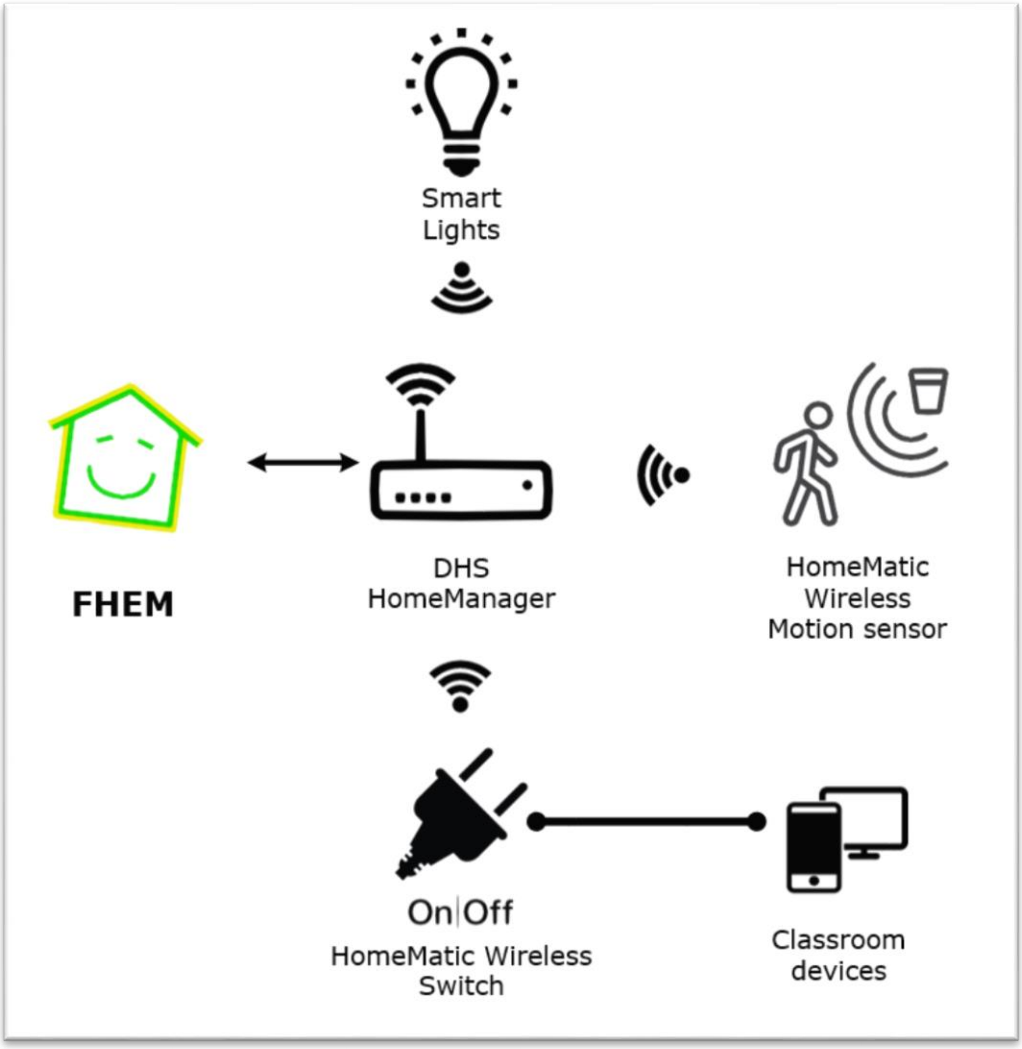

Fig. Design Diagram of Smart Classroom implementation.

Benefits

Sustainability

Most people don't think about turning school computers off and nobody unplugs their classroom electronics after leaving. Our solution provides convenience and ease of mind since those who do use school electronics responsibly won't need to worry about shutting down devices either. Everything happens unnoticed automatically. That small convenience is the social sustainability our concept brings.

Most of our projects sustainability is on environmental side. The whole idea of this concept is to save the last bit of completely wasteful power usage in classrooms. Although the impact of one room is small the combined impact of hundreds of classrooms saves a lot of energy thus reducing the emissions caused by electricity usage.

Energy and cost savings

A simple calculation example would be to estimate energy saving in one computer classroom since they have the most electronic devices in classrooms. We'll be using an LUT computer classroom in this example. In an LUT computer classroom there are around 15 computers and monitors. We can take standby power calculations researched by Lawrence Berkeley National Laboratory and use them in our calculations. According to the research an LCD display consumes 1.38W of power in sleep mode and a desktop computer consumes 21.13W on average in sleep mode. In these estimations the hardest part is estimating what portion of the year are the computer classes not in use. We can roughly say it is at least half of the day since the rooms are not used at most nights and daytime use is small on holidays and summer. We can also calculate cost savings estimates using electricity prices in Finland. With these numbers we can calculate some estimates.

Daily power draw (monitor + desktop)	1.38W * 12H + 21.12W * 12H = 270 Wh
Annual energy usage (for one class)	270Wh * 15 * 365 ≈ 1478 kWh = 1,478 MWh
Cost savings in a year at 4cent/kWh (one class & only computers + monitors)	1478 kWh * 4cent/kWh = 5912 cent ≈ 60€

Table 1: Calculations using estimated values

We can see that the amount of money saved is quite small in the scale of a university but when we include all the classrooms into consideration the energy savings and cost benefits can become significant. The real issue is the cost of implementation which in our example using switches would require multiple switches in each classroom and wouldn't be worth the investment. Our solution could be developed further and if we could manage a complete classroom with one switch the investment could be worth it. It is of course also a way of branding and enhancing the university's image. Green campus image sells, and this solution would bring another dimension to that.

X10 – Home Automation Protocol

X10 is an old home automation protocol. It was developed in 1975 in Scotland by Pico Electronics. The basic idea is that X10 uses power line wiring for signaling between transmitters and receivers (although wireless radio type solutions exists). X10 requires specific transmitters and receivers to work and all the appliances and lights must be connected to receiving appliance modules in, so they can be used.

X10 products function with two 4-bit codes, a house code and a unit code. House codes go from A to P and unit codes go from 1 to 16, which gives 16x16 unique addresses to be used. More on these codes in the in-depth portion.

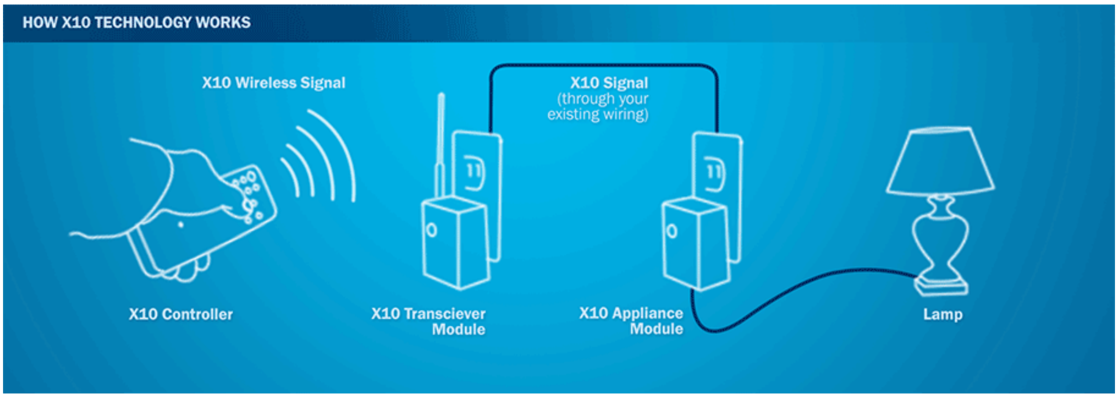

Figure 1: X10 setup example

In-depth

X10 sends 120 kHz RF signal bursts to the power line at zero crossing of the AC sine wave. The goal is to transmit close to the zero-crossing point to reduce interference (figure 2). The 4-bit codes transmitted are of course in binary. A binary 1 is a 1ms burst 120kHz at the zero-crossing point and binary 0 is an absence of a burst. Each four or five -bit code is transmitted in complementary alternate half cycles meaning that in each cycle half is the assigned binary and the other half is a complementary binary. For example, if first cycle half includes an RF burst (binary 1) the other half of the cycle should be absence (binary 0) (figure 3). (Smarthomeusa.com 2018)

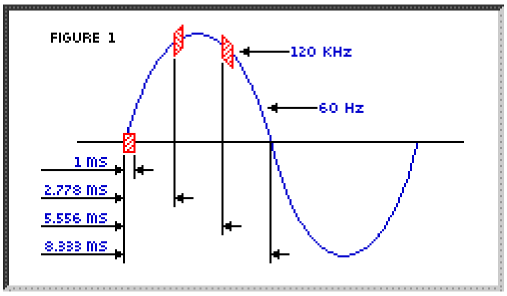

Figure 2: Example on AC sine wave

In addition to the 4-bit and 5-bit codes each transmission includes a Start Code which is constant (1110). This means every complete transmission consists of 11 cycles of the power line (figure 3). Two first cycles are the starting code. The four cycles after the Start Code signal the House Code (A-P) and the last five cycles represent the unit code. Unit codes can be either a Number Code or a Function Code depending on the last cycle (figure 4). Function Codes are preset commands like on, off, status etc. and Number Codes are functions set by the user. (Smarthomeusa.com 2018)

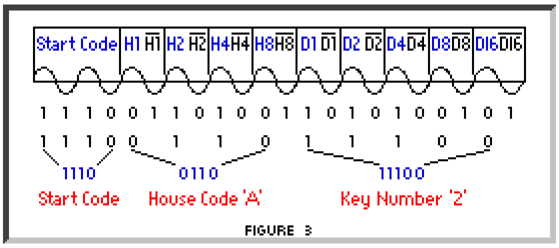

Figure 3: Example of 11 cycle transmission.

HOUSE CODES	H1	H2	H4	H8	KEY CODES	D1	D2	D4	D8	D16
A	0	1	1	0	1	0	1	1	0	0
B	1	1	1	0	2	1	1	1	0	0
C	0	0	1	0	3	0	0	1	0	0
D	1	0	1	0	4	1	0	1	0	0
E	0	0	0	1	5	0	0	0	1	0
F	1	0	0	1	6	1	0	0	1	0
G	0	1	0	1	7	0	1	0	1	0
H	1	1	0	1	8	1	1	0	1	0
I	0	1	1	1	9	0	1	1	1	0
J	1	1	1	1	10	1	1	1	1	0
K	0	0	1	1	11	0	0	1	1	0
L	1	0	1	1	12	1	0	1	1	0
M	0	0	0	0	13	0	0	0	0	0
N	1	0	0	0	14	1	0	0	0	0
O	0	1	0	0	15	0	1	0	0	0
P	1	1	0	0	16	1	1	0	0	0
					All Units Off	0	0	0	0	1
					All Lights On	0	0	0	1	1
					On	0	0	1	0	1
					Off	0	0	1	1	1
					Dim	0	1	0	0	1
					Bright	0	1	0	1	1
					All Lights Off	0	1	1	0	1
					Extended Code	0	1	1	1	1
					Hail Request	1	0	0	0	1 ①
					Hail Acknowledge	1	0	0	1	1
					Pre-Set Dim	1	0	1	X	1 ②
					Extended Data (analog)	1	1	0	0	1 ③
					Status=on	1	1	0	1	1
					Status=off	1	1	1	0	1
					Status Request	1	1	1	1	1

FIGURE 4

Figure 4: Available codes.

Benefits and disadvantages

Benefits:

- X10 uses existing powerline wiring (No need for ethernet or wireless solutions.)
- X10 is simple compared to newer alternatives
- Around for tens of years so many compatible devices, although devices are hard to find outside US
- Due to X10 being around so long many devices are much cheaper than alternative protocol solutions

Disadvantages:

- X10 must go through all the powerline to communicate which can cause noticeable delay
- Multiple X10 signals can interfere with each other and cause command losses. X10 also interferes with some radio equipment due to its RF usage
- Ultimately X10 provides less functionality than many alternatives
- 16x16=256 different addresses, which might limit usage

References:

Lawrence Berkeley National Laboratory (2018). Standby power summary table. Available: http://standby.lbl.gov/summary-table.html

Smarthomeusa.com (2018). How X10 works. Available: https://www.smarthomeusa.com/how-x10-works/#theory