# INTELLIGENT BUILDING CONTROL – UML (ZigBee)

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## Abstract

The article deals with the software design for controlling of intelligent buildings and houses. As a closer specification ZigBee[1] wireless technology was selected. Operation of the house is graphically designed by UML diagrams. The proposed system is intended to clarify and simplify the control process of intelligent houses [2]. The intelligent house should have greater efficiency, from view of resources, than a regular one.

**Keywords**: Intelligent buildings, Zigbee, UML

## Introduction

People have always been trying to simplify their life and decorate their homes. These gradual developments eventually lead to the construction of a fully automated intelligent house. With correct manner of automation increased comfort of intelligent house can be achieved and by intelligent control of individual subsystems energy saving can be achieved. This article provides a demonstration of calculation of heat losses in the intelligent heating control houses in comparison with classical control of heating [3].

Advantage of the software proposal through UML diagrams are their universality and easy financing. Proposed diagrams can be easily modified and adjusted according to users' wishes without the demand of radical intervention into the proposal.

## UML Formation

The initial step was the selection of the software environment. Microsoft's MS Visio was chose, which is part of the Office installation package. Visio presents a design environment for versatile use, which is supported by individual diagrams. The proposal includes the operation of following subsystems, which can be controlled: heating, cooling, security of people and property (security systems), fire protection, pull-down system, lighting, audio / video features and more. From the list of possible UML diagrams we chose three specific diagrams to describe the designed program: activity diagram, use case diagram and sequence diagram. By these diagrams was described mentioned proposal. [4]

The system shows a function with an emphasis on pre-established requirements:

- Easy operation
- Energy savings
- Security
- Control possibility of all available elements

## Description of the system proposal

For all chosen areas of operation were created UML diagrams. Scenarios of specific areas were also designed. In table 1 it's possible to see the scenario for the control of heating and cooling of the house.

*Table 1. Scenario of use case diagram for heating/cooling control*

| Step | Role | Action |
|---|---|---|
| 1 | User | Gives instruction to display the splash screen |
| 2 | System | Shows the splash screen |
| 3 | User | Starts by selecting heating/cooling |
| 4 | System | Brings up a menu for heating control |
| 5 | User | Selects from the menu |
| 6 | System | Brings up the menu for temperature change |
| 7 | User | Sets the desired temperature |
| 8 | System | Writes the data about the temperature change into thermostat |
| 9 | System | Applies changes |

Table 1 shows the process of communication between user and system and also demonstrates the scenario of the temperature settings in specific room. This section of system shows operation with the emphasis on temperature setting up and change. For better understanding is the temperature setting described by the graphical use case diagram in Figure 1.

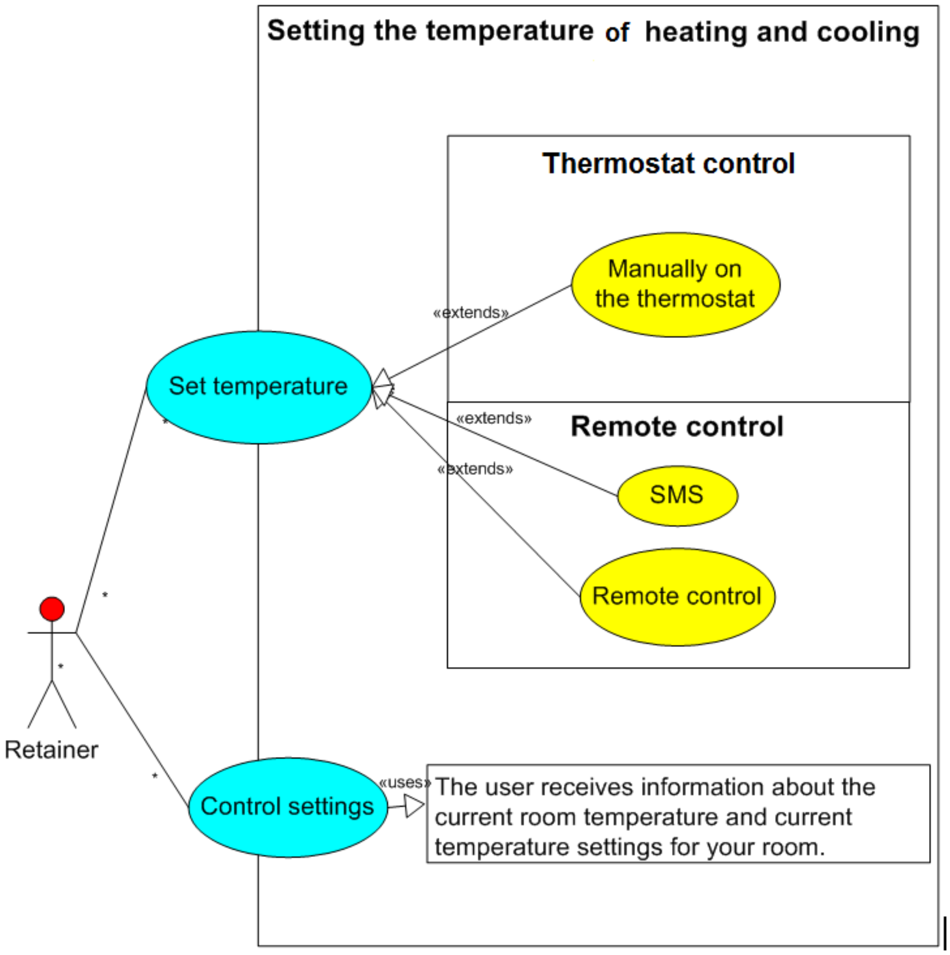


*Figure 1. Use case diagram of heating/cooling*

The diagram in Figure 1 shows possibilities of controlling and adjusting of temperature. The system is designed in the way that the temperature can be regulated for every single room separately. For a more specified description were created other diagrams such as diagram on Fig. 2a, 2b and sequence diagram on Fig. 3.

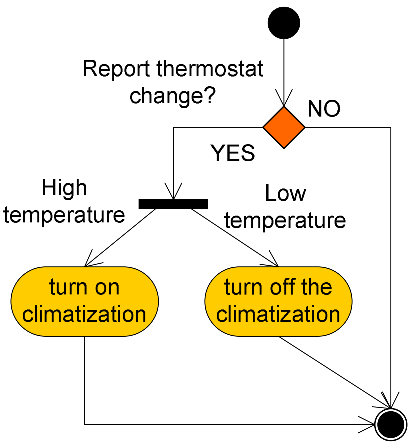


*Figure 2a. Automatic regulation of cooling with the help of thermostat*

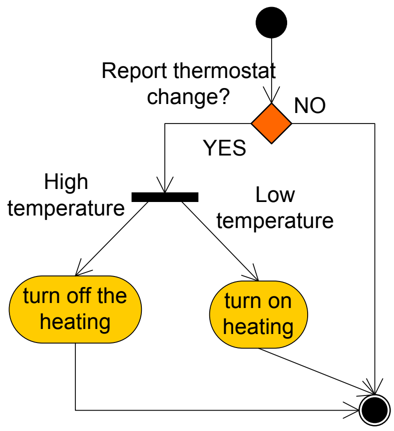


*Figure 2b. Automatic regulation of heating with the help of thermostat*

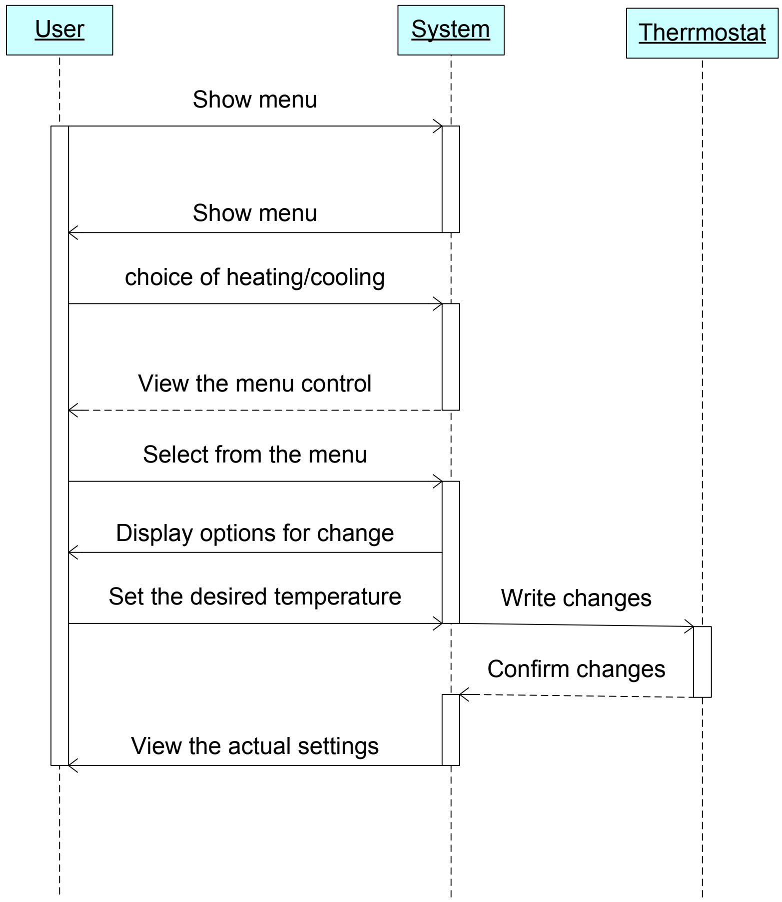


*Figure 3. Sequence diagram of heating/cooling control*

Other system components in the UML proposal are described similarly. Created UML diagrams are presented via web page. Web page is automatically created by Visio. The output (created web page) which displays diagrams that are converted into the GIF image format. *Microsoft focuses on its products, therefore the most compatible browser for the web page is the Internet Explorer.*

## Heating and cooling

The proposal of heating and cooling control is carried out with regard to comfort and easiness of use, but also places emphasis on energy savings. For demonstration of the energy savings we made a calculation of heat losses. In the calculation were the heat losses in the case of intelligent heating control with independently allocated thermostats in every room compared with heat losses by traditional heating control from one centralized thermostat. For the calculation of heat losses we considered the inner (light) room dimensions and wall heights (only in rough consideration, for demonstration purpose). The house is situated in Bratislava (Slovakia). Total area of the house is $128m^2$. The calculation was performed for the area of $106m^2$(without garage, it is not heated).

The average temperature determined for every day and hour in each month was used for calculation. The heating period was set since November to March. The average daily temperatures for Bratislava are in Table 2.

*Table 2. Average monthly temperature in the considered month*

| | NOV | DEC | JAN | FEB | MAR |
|---|---|---|---|---|---|
| Monthly average | 6,5 | 0,5 | -2,7 | -0,5 | 5,3 |

The calculation was carried out on the walls and windows of the house and it was considered also with insulation and heat losses through ceiling and floor into account. Then it was defined measurable thermal conductivity λ of the construction materials *(STN 730540)* and the thermal resistance R (1).

$$R_s = d / \lambda \qquad [m\ W\ K^{-1}] \qquad (1)$$

$$R_{zs} = d / U \qquad [m\ W\ K^{-1}] \qquad (2)$$

Results of thermal resistance:

- *Wall: $R_s = 2{,}45$* *[m W K$^{-1}$]*
- *Wall insulation: $R_{zs} = 0{,}1 / 0{,}04 = 2{,}5$* *[m W K$^{-1}$]*
- *Ceiling: $R = 0{,}33$* *[m W K$^{-1}$]*
- *Ceiling insulation: $R = 0{,}2 / 0{,}04 = 5$* *[m W K$^{-1}$]*
- *Floor: $R = 0{,}32$* *[m W K$^{-1}$]*
- *Floor insulation: $R = 0{,}1 / 0{,}04 = 2{,}5$* *[m W K$^{-1}$]*
- *For conductivity of windows and door $U = 1{,}1$* *[m W K$^{-1}$]*

In the last step it is necessary to evaluate the value of heat loss as a performance ratio to 1°C. This value was further multiplied by the difference between internal and external temperature. The calculation for walls is carried out in according to calculating equation (3). For windows it is a product of differences between internal and external temperature, surface S and thermal conductivity U (4).

$$Q_s = ( S / R_s + R_{zs} ).( t_i - t_e) \qquad [W\ °C^{-1}] \qquad (3)$$
$$Q_o = U.S.( t_i - t_e) \qquad [W\ °C^{-1}] \qquad (4)$$

where: $t_i$ is the internal temperature
$t_e$ is the ambient temperature
S is a surface (walls, windows, floors, ceilings)

The total loss was calculated as the sum of losses through windows, walls, floor and ceiling.

$$Q_c = Q_s + Q_o + Q_{ceiling} + Q_{floor} \qquad [W\ °C^{-1}] \qquad (5)$$

All-day heat loss is counted as the total heat losses of every hour. Weekly and monthly heat loss of the house is counted in the same way. The results of heat losses of the house for each month in the heating period November- March 2009/2010 are in Table 3. The left column values represent the house with intelligent heating system. The right column values are the heat losses in case of the heating regulated by one central thermostat. Evaluation of heat losses was simplified. Due to the attempt of the simplest demonstration of solution differences only „roughest“ heat losses were taken into the mention account.

*Table 3. Monthly heat losses*

| | Heat loss by intelligent control [kWh] | Heat loss by reg. thermostat [kWh] | Difference [%] |
|---|---|---|---|
| November | 730 | 889 | 18 |
| December | 1078 | 1234 | 13 |
| January | 1251 | 1411 | 11 |
| February | 1003 | 1132 | 11 |
| March | 819 | 920 | 10 |

Values in the last column of Table 3 reflect the energy saving in case of preferential use of intelligent operation system with the help of designed software instead of regulation by classic thermostat. It is obvious that the values are not negligible, so the system with intelligent control is more effective despite higher costs at the beginning.

According to Table 3 it is evident that the percentage differences of heat losses are average about 12%, which is very positive in the view of recoverability. These differences arose mainly due to the fact that in the case when is the house regulated by the intelligent system it is heated on minimum temperature while it is empty and therefore it leads to considerably lower heat losses. By classic regulation two modes were considered: day mode from 7:00 to 22:00, when the heating was set to 24°C and night mode from 23:00 to 6:00. In night mode the temperature in central thermostat was set to 20°C. The Figure 1 shows the progress of daytime internal temperature by intelligent regulation heating system.

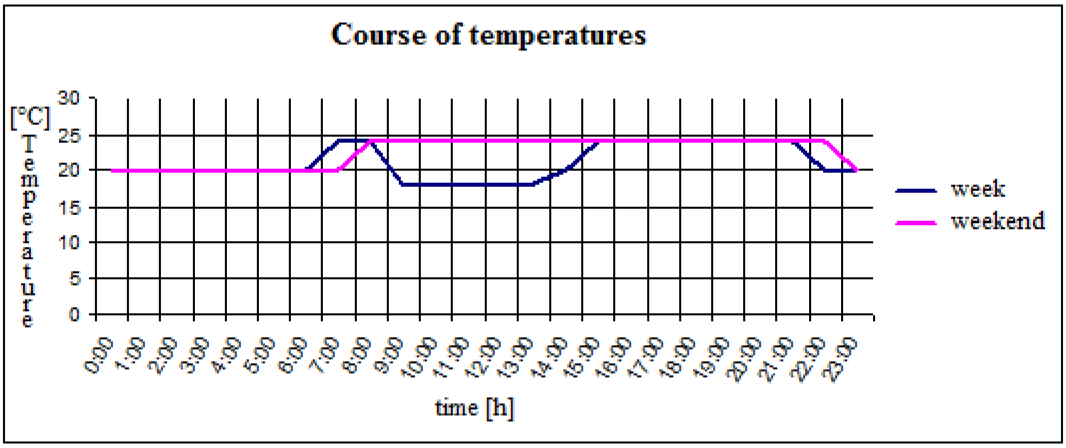


*Figure 1. Temperatures on weekdays and weekends for a specific room*

## Conclusion

Described system is designed with the emphasis on the user friendly demands (e.g. the most frequent functions are always “at hand”, in menu is the main light switch for a room allocated in upper left corner and so on). Software has a support of long-term flexibility which brings the possibility to reprogram the function keys by your individual needs. This action is controlled by software, therefore it is no need to replace specific module because of changing his function or to remove the module from existing implementation by required installing of new configuration.

The whole system of house control was designed by UML diagrams. By those diagrams was developed and designed software which is possible to program and to use in practice. The software is suitable as an input proposal for future software development. Diagrams also help in dealing with client, which want to implement the given proposal.

Intelligent heating control (proposed in mentioned manner) is able to decrease heat losses during heating season up to 12% per month (in the roughest average).

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