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SMART HOME SYSTEMS

SHVET

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1. INTRODUCTION

This guide provides an insight into a "smart house", that is a dwelling equipped with an „intelligent“ system, able to control several equipments and services, and is designed for all those who are planning a new building or renovating an old one, or for those who are simple curious and interested in what it means to have a "smart house".

Reading it you will learn which are the special features of a smart home system, which are the basic and advanced services a smart home can offer to you, what is the fundamental difference between a standard electric system and a smart home system, and a lot of other insider information that, as a simple customer, you will never be made aware.

1.1 WHAT EXACTLY IS A "SMART HOUSE"

Traditionally, houses, apartments, business premises and buildings for various purposes consist of separate electrical devices and systems where each of them requires separate handling and work independently of each other.
Usually, in our homes, we can not open the door from the TV remote or can not change the radio station by the wall switches. This is because every system works on its own and does not communicate with the others.

A "smart house" is actually a dwelling where an organized home automation system connects all the electrical devices to manage lighting, heating, air conditioning, ventilation, security (burglar) alarm system, audio and video system, call devices, energy control equipments, presence, automation (door, windows, blids, gates), technical alarms (for example in case of unwanted water spillage) etcetera .

A smart home is thus created by connecting separate parts of household installations such as lighting, heating, cooling, blinds, sensors, etc. into a common system. This form of automation results in a reduced need for human interaction and in an increase of comfort and safety, the provision of additional benefits and improved energy efficiency.

First of all, we must be aware that neither the electrical system nor the house itself are smart or intelligent, as they have not programmed themselves, they do not learn on their own from their mistakes and do not correct them (except in the case they are equipped with an artificial intelligent system!). However, „smart home system“ or „smart house“, as far as marketing is concerned, are well known terms that can be traced in all media.

Second, by increasing energy efficiency, i.e. reducing electricity consumption, we reduce our carbon impact, which is in line with current European and world policies.

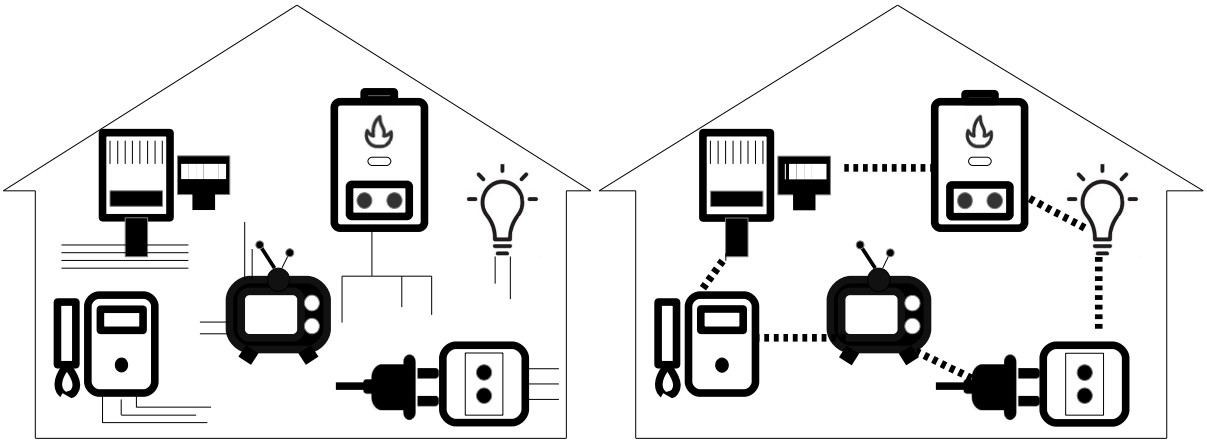

Fig. 1: standard electrical systems versus smart home system

1.2 HOME AND BUILDING AUTOMATION

When we think of home automation, or smart home systems, or domotics as it is often called, we thus think of smart thermostats, motion sensor controlled lighting and automated heating and ventilation systems. It can be defined as the use of a set of devices that controls basic home functions and features automatically and sometimes remotely .

But if we consider a building, instead of a house, the offered services and the users needs can be different. Most of the time, the rooms of a building are used especially during the day, there are dozens or hundreds or even thousands of devices to be controlled, there are equipments that usually we don't have at home (for example an elevator, fan coils, escalators) and a special attention to access control, energy saving, security (maybe the owner of an office building is less interested in entertainment and more interested in who can enter which space)

A common definition of Building Automation could be “An automation system that includes a comprehensive and coordinated control of one or more major system functions required in a facility.”

Smart home systems (or home automation systems) and Building automation systems (offen abbreviated to BA systems) are therefore "brothers": they share the same technologies and the same aptitude for control, with a slightly different point of view regarding implemented functions and number of controlled devices.

1.3 FUNCTIONS YOU CAN DO WITH A SMART HOME SYSTEM

Let’s take a look at some of the things a smart home system can do.

Lighting: lighting is the most important and most commonly used electrical thing in your home. At the moment, our lifestyle is such that we spend most of our time at home in the evenings. Since there is not enough natural light at that time, we replace it with artificial light.

In some rooms at home, it is recommended to use lighting with the possibility of dimming or even changing the lighting temperature (light color).

Such rooms are not just living rooms and bedrooms where you would like to achieve different light scenes, but can also be a hallway between the bedroom and bathroom or children's room.

Think about having to visit the toilet at night. In order not to injure yourself or break something, or by accident step on that sharp toy that your baby forgot in the middle of the hallway, it's a good idea to light up your path. In order not to be blinded by too much light, it is more pleasant if the light in the hallway shines with reduced intensity at night. We also would not like to wake up others.

A similar situation can occur if your child wakes up in the middle of the night due to bad dreams and you try to calm him (her) down and put him (her) to sleep as quickly as possible. If you turn on the light when entering the child's room, the child may think it is already morning and will be all happy, as his (her) dad or mom came to play in his room.

On the other hand, many children find it difficult to fall asleep in pitch dark. The dim light in his (her) room can help you slowly put him (her) to sleep at lower and lower light intensities.

Smart homes usually have lighting outside as well. With different lamps, you can create different scenes and atmospheres in front of your home. If we are talking about the case that you are outside, it is advisable to use the option of remote switching on and of these lamps. This will allow you to operate the outdoor lamps with a remote control (or smartphone) in your pocket as needed, without having to go into the house each time.

Fig. 2: outdoor lighting

With a smart home system you are able to control all kind of lamps, in on/off or dimming mode, choosing the best interface suitable for you (a simple pushbutton or a remote interface, for example using your smartphone or a remote controller). You can decide which lamp or group of lamps to turn on or off, you can set a certain time of the day when you want the lamp to turn on, you can decide some “scenes” (the first lamp at 100% of its intensity, the second at 50% and the third one at 20%) or also some lighting profiles (for 1 hour the lamp is at 70%, then for 25 minutes is at 40%, then for 5 minutes is at 15%...)

You can also use another feature for the same thing, as your home wireless network always knows where you are because you always have your smartphone with you. This way, the driveway to the house will light up as soon as you get close enough to your home without having to turn it on yourself over the phone.

At night, set the outdoor lighting to auto-off so it won’t light up all night. It will turn on again if someone invited or uninvited comes to visit. Your smart house will inform you about his arrival by outdoor lighting.

Heating: heating is one of the sub system always present in a dwelling. Some users maybe live in a building and have a central heating with radiators. In this case you can install thermostatic valves, connected to the smart home system, and control them room by room, setting different temperatures. Others maybe live in a townhouse or in a villa. In this case you can have an underfloor heating with an hydraulic manifold, and can install more zone valves with actuators connected to the smart home system.

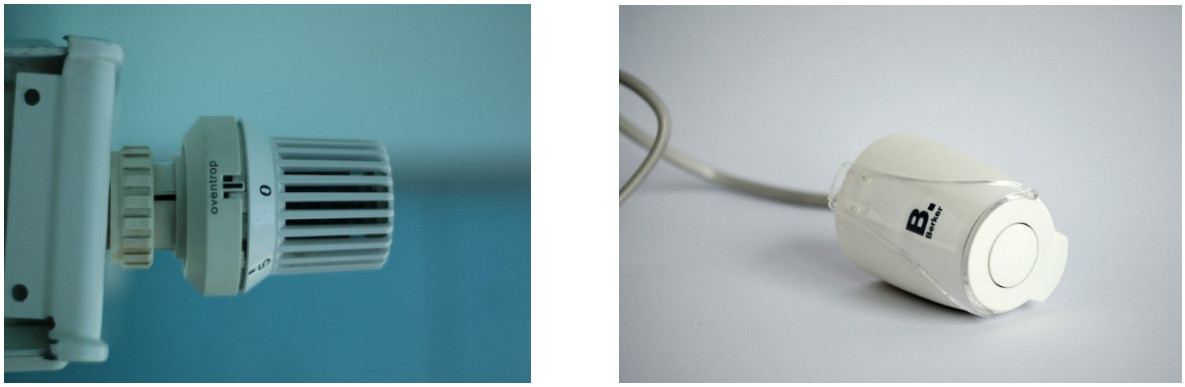

Fig. 3: thermostatic valves

With these devices you have control over the heating at home even via a smartphone. An added value is that it even can save on your heating bill, by heating only when and where you need.

Scenes (scenarios): a „scene“ is used for setting a group of commands that acts on their actuators with different values. Typical examples are lighting scenes for different occasions (party, romantic dinner, TV watching etc).
If you have a house with two or three floors the task of closing or opening all the windows can take a certain amount of time. But if you have a smart home system, at the front door you can

install a switch on the wall, with which you can turn off all the lights in the apartment at the moment you leave home with just one push of a button. If this example is not sufficient, try to imagine to have a small hotel or bed&breakfast with 10 rooms. The possibility to send a command to several different actuators can be very useful.
A scene does not have to deal only with lighting. A „cinema scene“ could for example involve a specific management of lights, the rolling shutters of the room all lowered, the video projector on and the motorized screen activated.

Anti-burglary system: most of the smart home system producers sell devices that provide anti-theft functions, from the lowest level (just presence sensors and a siren) to the highest one (connection with the police or with a security service in case the anti-theft system fires).
If a burglar breaks into your home the smart home system can also trigger the rapid blinking of all the lights in the apartment (similar to a stroboscopic light) in order to confuse the burglar as much as possible. Hopefully, a loud alarm and crazy flashing lights will be enough to turn the burglar escaping into the night.

Presence simulation: even the best anti-burglary system in the world will not distract a determined burglar. But there is something the smart home system might be able to do.

Do you remember the scene from the movie Alone at Home, starring Macauley Culkin, in which two burglars stopped a van in front of their house and saw that there is a party going on in the house? There was music playing in the background, a cardboard-cut figure of Michael Jordan riding around the room on a children's train. With the help of various strings and levers, Kevin managed to control some other puppets too, thus creating the impression that someone was at home.

A smart home system can provide a presence simulation feature that is much more advanced than the aforementioned movie story. It records your commands during any day, such as:

- when individual lights in the house were turned on and off,
- raised and lowered blinds in each room,
- changed light luminous in rooms,
- changed color of RGB LED lamps ...

When you leave home for a long time e.g. holiday, you can activate the presence simulation function by pressing a single key before leaving the house. This one will play all the saved commands so that on the outside it will look like you are still physically at home.

This way, you can record what’s going on for a day, a week, or even a month just to make the playback of the recording look as real as possible.

The described operation represents a great advantage in terms of safety compared to simple timers that turn the lighting on and off every day at the same time. A potential burglar can observe your home before the burglary and find that the blinds go up and down, the lights turn on and off at completely different times during the day or week. This can already make a difference whether he will break into your home or not.

Alarm clock and room control: if you want to be sure to wake up at the right moment, for sure you will use an alarm clock.
A smart home system can give you the possibility not only to set more alarm clocks, but also to be connected to the children's room (for example with a tablet or a smartphone) and at once turn on the lights in the room to the maximum and raise the blinds.
Of course, a teenager can get up and simply turn off the lights and lower the blinds back. With a simple push of a button, you can lock (block) the operation of the switches that operate the lights and blinds in the child's room, thus preventing it.

Weather control: your smart home system can be equipped with a weather module, able to measure data such as rain intensity, humidity, wind speed and so on. In case you are not at home and suddenly it starts to rain, the system can close the windows, in order not to wet the floor, for example. Or in case of strong wind, it can raise the awning, in order not to damage it.

Automation: when you get home, you can use the remote control or smartphone to turn on the opening of the door before the entrance to the house and the opening of the garage door.
Using electrical motors, managed by smart actuators connected to the smart home system, you can automate almost everything: doors, windows, blinds, gates, screens, even armchairs and sofa.
In the same way you can control also third party devices, that can be integrated in the smart home system control, like stairlift, equipments for disabled and so on.

Safety: undoubtedly, the safety of those close to us is more important to everyone than money and material goods. Protecting your home is absolutely necessary today, as it provides you with compensation in the event of a fire, burglary ... However, you must do everything you can to prevent such accidents.

Various events detected by sensors in the smart home as well as data on heating, room temperature, light status, ventilation and so on are processed in real time. This means that the system will notify the user of the event as soon as it occurs and not later. At the same time, all these events can be automatically stored in the event database, for the needs of possible later analysis. When you get home, you can watch these events or not, and you can receive the most important things on your smartphone even when you are not at home.

The smart home system provides a connection between various important functions about safety. With the alarm system you can connect the electrical installation as well as sensors of movement, smoke, CO_2, water spill, open windows and doors, energy consumption measurements. With their help, you can protect your home from damage and reduce side effects due to accidental events.

Energy efficiency: households use energy for various purposes: space and water heating, space cooling, cooking, lighting, electrical appliances and other end-uses. Most of the time a user is not aware of the energy consumption required by the used equipment, and in this case just only the opportunity to monitor it could reduce energy wastes.

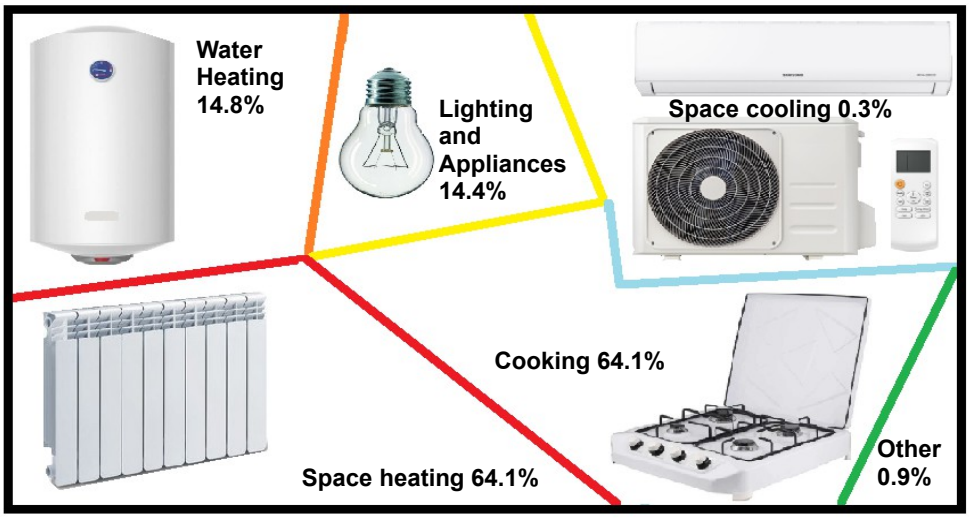

Fig. 4: energy consumption in EU households

A smart home system can measure and display the energy consumption of all the devices connected to the electrical system, can set a power threshold that must not be exceeded in order to prevent the general circuit breaker trigger, can activate an appliance when the energy tariff is more convenient, can turn off light and heating when nobody is in the room. Beside this, it can be interfaced with every kind of renewable energy production system.
Smart home systems, with their smart thermostats, presence sensors and energy monitoring devices are forging a path to a brighter, greener future – and saving us some cash along the way.

Remote control of your house: inside you house, to control all the devices and functions you can use switches, push buttons, touchscreens and even a voice control interface.
But if you are really in a hurry from home and you only remember later on the road or at work that you did not press the „Turn off all lights“ button when you left, you can simply log in to your smart home system with your smartphone, tablet or computer and do so. The majority of the smart home system manufacturer gives you today the possibility to have a remote control interface, and most of the time it consists in a web page where you can log in (with your name and password) and check the state of every equipment and every subsystem.

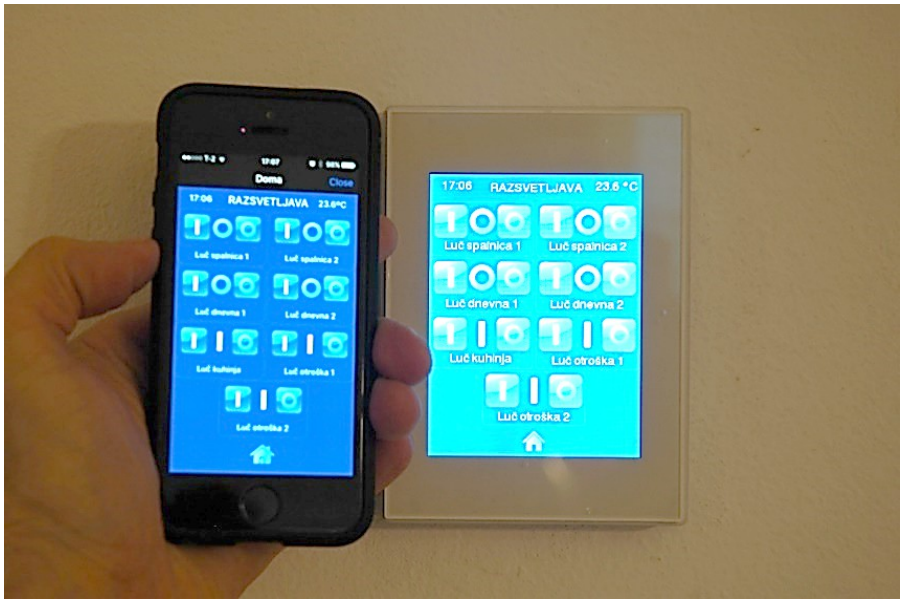

Fig. 5: smartphone control of the house

We have listed here the most common and used set of functions a smart home system can perform, but there are endless possibilities of usage. With such a system you can control the watering system, you can intergrate smart appliances, telemedicine devices and every type of electrical equipment you may want to use.

2 DIFFERENCE BETWEEN A SMART HOME SYSTEM AND A STANDARD ELECTRIC SYSTEM

2.1 ELEMENTS OF A CLASSIC RESIDENTIAL INSTALLATION

Wires and connections

The voltage used throughout Europe (including the UK) has been harmonised since January 2003 at a nominal 230V 50 Hz . It is distributed by means of two conductors called Line (letter L, color brown or black) and Neutral (letter N, color blue). Between them there is an alternating voltage (AC) with sinusoidal shape.
It is said that current flows from the line conductor (cable) through the load (for example the lamp or an appliance) and then it returns to the power supply source by means of the neutral conductor . This is not perfectly true, because the powerline in our homes is AC, thus every half period the current direction changes. Anyway, for convenience we can consider the line cable as the „supply“ and the neutral as the „return“.

The correct choice of conductor is determined by the purpose of the end device, i.e. its power. The most important factor when choosing the right cable is the strength of the current it can withstand permanently. For example, a 1.5 mm^2 conductor and a 10 A protection are most commonly used for lighting, while a 2.5 mm^2 conductor and a 16 A or larger protection, depending on the consumer, are used for sockets.
When calculating the conductor, the voltage drop from the distribution cabinet to the home connection measuring cabinet is also calculated. The permissible voltage drop that the conductor must not exceed is 4%.

All the loads in our electric plant are connected like in the figure below

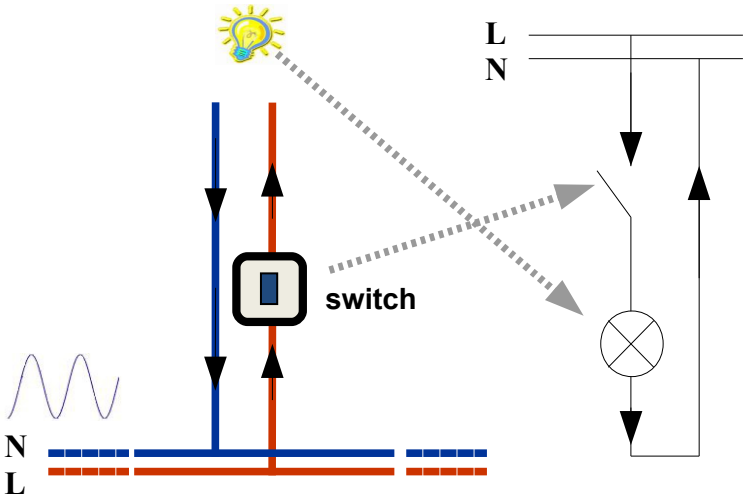

Fig. 6: load and switch connection in a standard electrical system

There is also a third wire, called “Protective Earth” (letters PE, color green/yellow)
This wire brings earth potential to all electrical outlets for safety reasons. Appliances with metal chassis are connected to earth wire so that should any insulation fail within the appliance, current will be shorted to earth, thereby tripping the breaker or melting the fuse to that circuit, and protecting human's life.

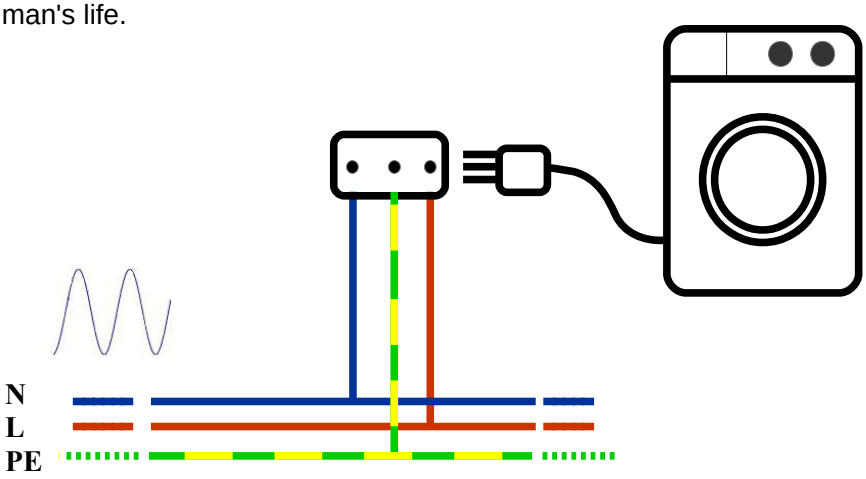

Fig. 7: protective earth cable

In a standard electrical system, the switch is the point where the user decides to turn on or off the load (thus is the command) and is also the point where the line is connected or not to the load (thus is the actuator).

Protective devices

Protective devices are installed in buildings in order to protect the performed electrical installation from failure due to excessive heating and short-circuit current, and to protect people from electric shock.
Some examples of protection devices are:
1. Circuit breaker: serves to protect the conductors from overcurrent from the place of their installation to the load, but not the load itself.

Fig. 8: circuit breaker

2. Residual current circuit breaker: is also called “differential switch”, because it monitors the input and output current, and if a difference is created, the circuit is interrupted (the missing current could flow into a human's body).

3. Combined circuit breaker: is a device that combines the functions of an automatic circuit breaker and a residual current device and is therefore a practical element if we have a problem with lack of space in the distributor.

Fig. 9: combined circuit breaker

4. Switch-disconnectors: is a device used to assemble and insulate electrical circuits and is characterized by a high degree of compatibility and large amounts of short-term withstand currents.

Fig. 10: switch-disconnectors

5. Fuse: is a device that protects against short circuits. Most of the time it consists in a filament of a certain diameter, calibrated to support a certain amount of current. When the current exceeds this amount, the filament breaks and the circuit is interrupted.

Fig. 11.: fuse

Switches and push buttons

Switching elements are used to switch electrical equipment and devices on or off. Some examples of such elements are:

1. Switches: are bistable devices used to turn on and off a load (a lamp or an appliance). They don't have, let's say, a “rest” position: when they are pressed, they stay in the position they have been moved to, until another pressing changes this position. One position corresponds to the state ON and the other to the state OFF, with a fixed assignement.

Fig. 12.: switches

2. Push buttons: are monostable devices used to turn on and off a load. They have only one stable position, and when released, they automatically come back to this stable position. In a standard electrical system, if we want to use a push button to control a load, we must use also a relay that, with a single trigger, can change and maintain its state

Fig 13: pushbutton (left) and double pushbutton (right)

3. Shutter button: has a function of raising and lowering the blinds.

Fig. 14: shutter button

4. Pulse switch: is an electronic remote switch with energy saving function. If we do not turn off the light within the set time by pressing the button, it will turn off automatically and allow connection with 3-4 conductors.

Fig. 15: pulse switch

Relays

Relays are electromagnetic devices made up by a coil and one or more contact. When the coil is energized by a current, it becomes a magnet and attracts a metallic moving element connected to the contact, that changes position and goes from one state (for example ON) to the other (for example OFF) or viceversa. Usually, the coil is connected to a push buttons and the contacts is located between the power line and the load, so when the button is pressed the load is connected to the power line.

Fig. 16: relay

Sockets

Electrical sockets are elements used to establish an electrical connection between the electrical installation and portable consumers.

Fig. 17: electrical socket

Timers

A timer has the function of automatically switching off electrical devices using a digital timer.

Fig. 18: timer

2.2 STRUCTURE OF A SMART HOME SYSTEM

While in a standard electrical system the command and the power connection functions are performed by the same device (the switch), in a smart home system these two roles are separated: the command function is performed by a „smart switch“ and the powerline connection function is performed by a „smart actuator“.
Both the commands and the actuators must be able to transmit and receive information, thus they are connected to a communication bus which is also the infrastructure that powers them. This bus runs through all the smart modules of the system, starting from a power supply device.

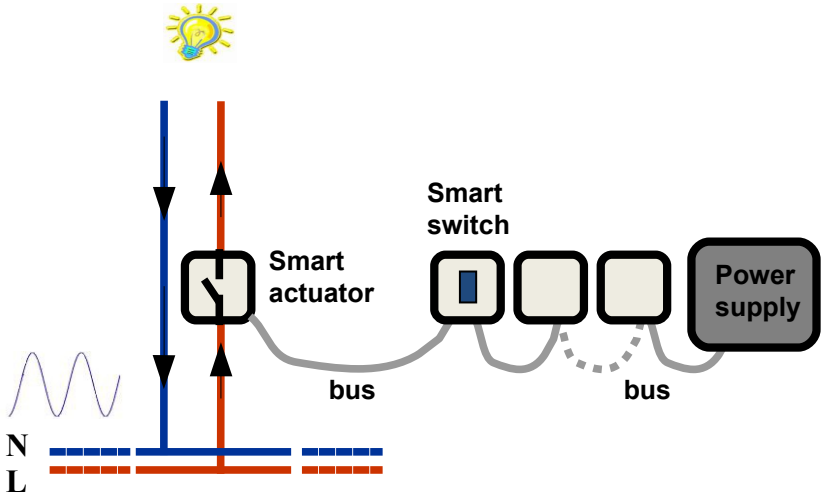

Fig. 19: smart home system infrastructure

A smart home system is a modern electrical installation of a building, i.e. a set of decentralized electrical output elements for the purpose of electricity distribution to terminal devices, decentralized communication and input elements for information collection, management and communication, wired to a common communication bus for interaction, automation operation of

various building systems and devices, with the ability to optimize energy consumption in the building.

In order for devices to be able to exchange information with each other, they must be configured to understand the protocols that allow them to communicate with each other.

The fact that a smart home system is decentralized means that there is no central vital point (e.g., a central computer or controller) that would cause the system to suddenly shut down. Each communication element of the system is parameterized separately and in case of failure of one element, the others continue with normal operation.

In a smart home system we distinguish between the energy distribution part of the installation (230 V) and the communication part of the installation (BUS) connected to low voltage (typically in the range 20 – 30 Vdc) as shown in Figure 20.

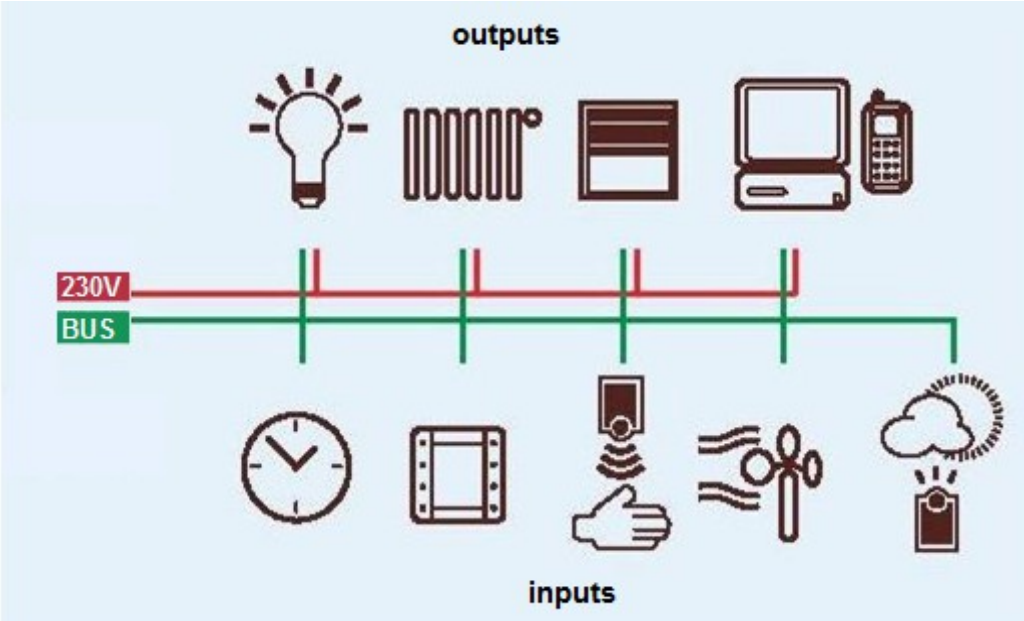

Fig. 20: energy and bus distribution in a smart home system

Each end device is connected to the energy part of the installation and to the communication bus via the appropriate actuator, while control devices (pushbuttons, switches, sensors, thermostats, etc.) are connected only to the communication bus.

Since all elements, input and output, are connected to the communication bus, interaction between different systems and devices is possible (e.g. information on current temperature, wind speed, glare, light intensity, space occupancy, measured by a sensor and can be used as input information for each device in the system).

Due to the possibility of interaction between different systems a higher level of regulation and management of the system is achieved, thus enabling greater energy savings in the building.

Once a smart home system is implemented, it has the ability to repurpose and change the functionality of executive functions (e.g., reorganize or repurpose space) by adding new controls to the existing communication bus or by replacing the actuator itself.

2.3 MODULES OF A SMART HOME SYSTEM

In functional terms, the components of a smart installation can be divided into:

- system elements
- input elements
- output elements (actuators)

Some examples of system elements are:

- Power supply unit: it generates a low DC voltage that powers all the smart modules of the system. Overlapped on this voltage there is also a digital small signal that allows data communication among all the input and output elements .

Fig 21: power supply unit

- Gateways or interfaces: allow the integration of other devices that use other communication protocols. For example, below we can see the DALI/KNX gateway used to add to the system some lighting features, equipped with the DALI control protocol, on the KNX communication bus.

Fig. 22: KNX/DALI gateway

- IP router: allows the smart home system of the building to be displayed on various devices (PC, tablet, smartphone) via a WEB browser. Also with an IP "router" we can configure and manage smart home system remotely, from another location.

Fig. 23: IP router

- 230 VDC / 24 VDC rectifier: serves as a low voltage (24 VDC) power supply for some smart home system elements (e.g. meteorological stations)

Fig. 24: 230 VDC / 24 VDC rectifier

- Bus cable: used for wiring all elements of a smart home system and connecting them into a single control - monitoring system.

Fig. 25: bus cable

Some examples of input elements are:

- The outdoor weather station (meteorological station) is equipped with sensors to monitor and measure current outdoor conditions (wind, rain, temperature, daylight). It is placed on the front of the building.

Fig. 26: weather station

- The window contact is placed on the window to monitor the opening of the blind.

Fig. 27: window contact

- Input binary module: allows non-smart information from input elements (eg window contacts, switches, thermostats, hygrostats) to be integrated into a smart home system

Fig. 28: input binary module

- Room control unit: equipped with a temperature sensor that measures the temperature in the room. There is a screen on which it is possible to see the set and current values with programmable keys, for manual control of room devices and equipment (eg lighting, blinds, fan coils).

Fig 29: room control unit

- Multi-smart button: equipped with several programmable buttons, for the purpose of manual control of room devices and equipment (e.g. pumps, fans, valves).

Fig. 30: multi-smart button

- Digital clock: enables the function of real-time monitoring and switching on or off the elements of the smart system according to the annual time program. It has the ASTRO function (switching on / off the outdoor lighting depending on the geographical position of the building and the season of sunrise / sunset) and contains several program channels.

Fig. 31: digital clock

- Multi-ceiling presence and lighting sensor: is a passive sensor for the presence of people and the amount of daylight, designed for ceiling mounting, with a detection angle of 360°.

Fig. 32: multi-ceiling presence and lighting sensor

Some examples of output elements are:

- Switching actuator: is equipped with relay outputs and is used to turn on and off various electrical devices (lighting, motors ...).

Fig. 33: switching actuator

- Roller shutter actuator: is equipped with four 3-position switching outputs (opening, stop, closing), for connection of electric motor drives of window blinds.

Fig. 34: roller shutter actuator

- Fan coil actuator: designed to control the fan coil with variable ventilation speeds.

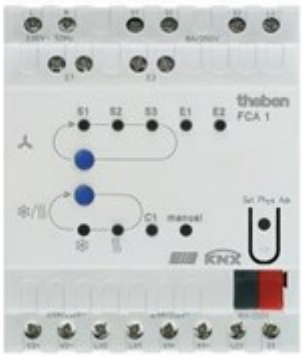

Fig. 35: fan coil actuator

3 SMART HOME SYSTEM TECHNOLOGIES

3.1 OVERVIEW OF AUTOMATION AND CONTROL TECHNOLOGIES

You can find many different smart home systems on the market.
Every system is based on a specific technology used to exchange data among all the smart home system modules.
These different technologies differ in performance, scope, data rate, etc.
Some of these technologies are:
- Interbus: is a sensor / actuator data bus. It is characterized by a ring topology based on the RS485 interface, which brings some advantages, namely: the ability to transfer data within the system for a length of as much as 13km and easier fault finding in critical situations. The disadvantage of this system is that when one device fails, all the others also fall out of operation. Devices on the bus do not have to have addresses due to the ring topology, the position inside the ring is sufficient for identification. The data transfer speed on this bus is up to 500kbit / s.
- P-NET: is a master-slave bus type. It uses the RS485 interface, and it is possible to use the TP or RS232 interface, but with a reduced data rate. The maximum length of such a bus is 1200m, and the data transfer speed is 76.8kbit / s.
- Profibus: uses the RS485 interface or optical cable as the data transmission medium. There are three variations of this technology, Profibus-FMS (fieldbus message specification), Profibus-DP (Decentralized peripherals) and Profibus-PA (Process Automation), which cover a wide range of possible applications and can cooperate with each other.
- CAN (Controller Area Network): specializes in automotive applications due to its high data transfer rate of 1 Mbit / s and short data transfer length of 40 m. It uses the CSMA / CA (Carrier Sense Multiple Access with Collision Avoidance) method when transferring data.
- LonWorks: is an open networking solution for building automation and control networks that was developed by the American company Echelon. It is designed in such a way that it can be used in centralized building automation controllers as well as in decentralized building control components. LONWORKS is a standardized bus system (ANSI/CEA-709.1-B and EN ISO/IEC 14908) that enables intelligent devices to communicate with each other over a locally operated control network. LON stands for Local Operating Network. See the Appendix for further technical information about the Lonworks technology
- BACnet: BACnet (Building Automation and Control Network) is a standardized data communication protocol developed by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) for use in building automation to enable devices and systems to exchange information. BACnet is used in numerous building automation systems worldwide and acquired the international ISO 16484-5 standard in 2003. BACnet evolved from the need for a standardized data communication protocol that would enable the various automation and

control components in a building to communicate with each other, ensuring interoperability and manufacturer independence. See the Appendix for further technical information about the BACnet protocol

- ZWAVE: Z-Wave is a recent and new generation wireless system, originally developed by Zensys in Danmark, that allows all electronic elements to communicate both with each other and with the user wirelessly. After the first installations a Z-Wave Alliance was established in 2005 as a consortium of companies that make connected appliances controlled through apps on smartphones, tablets or computers using Z-Wave wireless mesh networking technology. It uses radio signal with a frequency of 868.4 MHz and a maximum emitted power around 20 – 30 mW. In doing so, it uses simple, reliable, low-power radio waves that easily pass through walls. Z - Wave uses the Mesh network topology, so it can extend much longer than the radio waves of a single unit. The system is very simple and easy, both to install and to use, and practically does not require much knowledge and time to install and start operation. This system is used especially for homes with do-it-yourself solutions.

- ENOCEAN: Enocean has developed a technology based on efficiently exploiting the smallest changes in the environment to capture the energy needed, which is then converted into electricity, which then serves as an energy source to send radio frequency signals from sensors to actuators. All Enocean components operate without batteries and are designed to operate without maintenance. The simplest example of a product based on RF protocol is a battery-free, wireless-free lighting switch. By pressing such a switch, you "put" so much energy into it that the switch produced as much electricity as it needed to send a weak RF signal to the actuator to turn on the light. Or by turning the handle on the window you produce so much energy that the handle sends an RF signal to the valve on the radiator which tells him that the window is open and that the valve should close because you want to ventilate the room. The system requires shorter wiring time because no wiring is required between the switch and the light.

- MODBUS: Designed by Gould Modicon, is supported by most programmable logic controllers. It relies on the Master/Slave protocol. It is very simple and easy to use, so it is used by both controller manufacturers and manufacturers of building installation equipment. It has become very popular because it is free. It is limited due to the simple exchange of data and is therefore not used for more complex needs.

- X10: X10 X10 is a protocol for communication among electronic devices used for home automation. It primarily uses power line wiring for signaling and control. A wireless radio based protocol transport is also defined. It was developed in 1975 for remote control of home appliances. It was the first home automation technology and is still available all around the world. Unfortunately, it is obsolete today as it is very slow (around 20 bit/s). Due to its small set of commands and poor reliability, it is not very widespread in Europe today.

- ZIGBEE: The ZigBee specification describes the infrastructure and services available to applications running on the ZigBee platform. It specifies a high-level communication protocol that uses low-power digital radio signals based on the IEEE 802.15.4 standard for the needs of wireless networks (medical devices, smoke and burglar alarms, building automation). The technology itself is simpler and cheaper than with other wireless networks such as Bluetooth. The most powerful ZigBee node contains only 10% of the software contained in a typical Bluetooth or ordinary wireless network, and the simplest only 2%. Arrangements are currently underway between the ZigBee and the BACnet Commission to build a connection between the wired and wireless open protocol.

- DALI: DALI (DALIa, DALIb) is a digital communication protocol designed specifically for lighting circuits. DALI is very suitable for making scenes and getting feedback on faulty lamps. Therefore, it is very suitable in combination with building automation, where remote monitoring and service reports are required. DALI was introduced in 1999 by manufacturers of electronic ballasts who wanted a standardized digital control protocol for electronic ballasts. It is made so that it is very easy to install and configure. All actuators, controllers and sensors are connected to each other with one communication cable. The DALI system consists of electronic ballasts, switches, sensors, control interfaces and 1-10 V controllers. DALI is not a building automation system but only a lighting management system. Of course, the DALI system with use of different interfaces can be an easy (and cheaper) addition to various building automation systems such as e.g. BACnet, Lonworks or KNX.

- DMX 512/1990: The DMX 512/1990 is a digital data transmission standard for dimmers and controllers operating in DC mode. It can manage up to 512 channels. Data is transmitted in packets. Each package updates all built-in devices. Each package consists of up to 513 frames that mark the beginning and end of each package. We do not access the devices directly, but the information we send to the device is defined in a specific framework of each package. The DMX standard is widely used in theatres, discos and clubs because many special lamps, strobe lamps, fog machines and other devices implement it onboard.

3.2 WHY KONNEX

Amomg the others, it exists also the Konnex standard.
Konnex, abbreviated in KNX, is not the name of a company, but is instead the name of a technology, of a standard. This technology has been standardised and recognized all over the world with a European regulation (EN50090), a Chinese regulation (GB/T 20965), an American regulation (ANSI/ASHRAE 135) and with a worldwide regulation (ISO/IEC 14543-3)
There is not only a single manufacturer in the world that produces KNX elements. Instead today more than 419 manufacturers are registered to the Konnex association. Together, these manufacturers produce more than 7,000 different KNX elements. This number of manufacturers

ensures a 100 percent supply of KNX elements throughout the life of your home. 419 manufacturers can’t fail overnight.

Most of the other smart home systems rely only on their own production of elements, so they can fail faster and thus interrupt the supply of spare parts to your system.

Besides the KNX manufacturers, there are more than 70631 registered KNX partners (let's say „experts“ or „designers“) in the world, and these are the people who design and configure KNX systems. And the number is growing day by day.

This means that you can have the entire life of your home without worrying about any spare parts and service needed for your smart home.
It is difficult for the other competitors to provide such a long support.

These are the reasons why, in this guide, after having showed you a general picture about smart home systems, we have decided to concentrate on the Konnex standard.

4 KONNEX

4.1 HISTORY OF KNX/EIB AND KONNEX ORGANIZATION

Konnex was founded in 1999 with its headquarters in Brussels (Belgium), and was formed by the association of the three European organizations that were engaged in the development of intelligent electrical installation systems. EIB organization from Belgium in front of the EIB system, BCI from France, which developed the Batibus system, European Home Systems Association from the Netherlands with its EHS system. After its founding, Konnex consisted of nine members, but the number rose to more than a hundred at the end of 2003. Today, these companies cover more than 80% of the European market for electrical installations and white goods. Some of the partners of this organization are Siemens AG, ABB, Sace S.p.A., ABB Schweiz Normelec (Levy Fils AG), ABB Stotz-Kontakt GmbH, Merten GmbH & Co. Moeller Gebäude automation GmbH, Schneider Electric (Lexel AS), Schüco International KG, Viessmann - Werke GmbH & Co. KG. WERK II and many others.
The full list of Konnex members can be found at www.konnex.org.
At the end of 2003, the KNX standard was approved by CENELEC (European Committee of Electrotechnical Standardization), as a European standard for electrical installations used in construction under the EN 50090 standard.

4.2 TRANSMISSION MEDIA

There are four main ways of signal transmission in the KNX system:

1. Twisted pair (TP): is a couple of thin conductors twisted along their path, and it serves as a mean of communication between devices in a KNX installation. It is called BUS. It uses a safety low voltage (SELV), which does not exceed 30 V. A safety power supply is necessary - so that in case of failure higher voltages can not occur (safety transformers with separate windings, motor-generators with separate windings, batteries , etc.). The conductors and housing of the SELV must not be earthed.
The data transfer rate is 9600 bit/s, and the data travel serially, one byte at a time, via asynchronous data transfer

The following maximum BUS wire lengths are allowed in KNX installations:

power supply	element of KNX installation	350 m
element of KNX installation	element of KNX installation	700 m
the entire length of the BUS wire		1000 m
minimum distance between two power supply units on one line		200 m

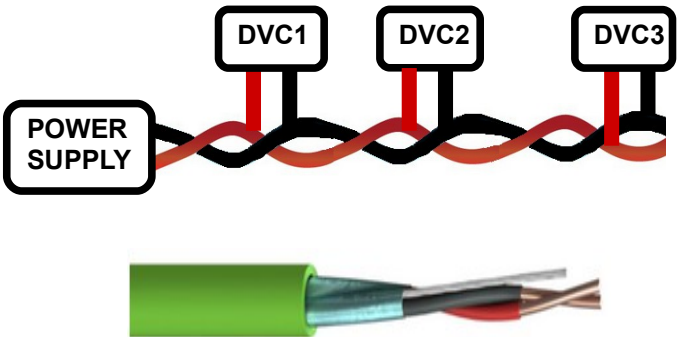

Fig. 36: twisted pair (DVC = device)

2. Powerline (PL): using the existing electricity cables in a building as KNX communication medium is a cost-effective way of retrofitting a building with KNX. In KNX Powerline there is no need to lay a dedicated bus cable: the electricity cables already installed (one of the three phases + the neutral wire) themselves become the communication medium. The data signals are superimposed onto the mains voltage. In KNX PL the data transfer rate is 1200 bit/s. Logical zeros and ones are transmitted via spread frequency shift keying (S-FSK). A signal of frequency 105.6 kHz sent by a transmitter corresponds to a logical zero, while a logical one is represented by a frequency of 115.2 kHz . The great advantage of this way of implementing the KNX system lies in the fact that it can be installed in already installed electrical installations. Every module has inside its electronic board a sort of “powerline decoder”, which is able to overlap and extract the data signal to and from the powerline cables.

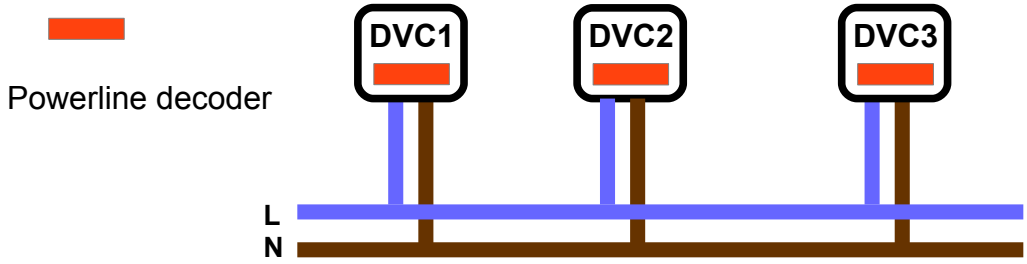

Fig. 37: powerline communication

3. Radio frequency (RF): radio is always an appropriate communication medium in those situations where it is not possible to lay new cables in the building (e. g. for sensors in inaccessible areas). Theoretically RF could allow all technologies in a building to be controlled wirelessly, but this will remain the exception rather than the rule. KNX RF uses frequency modulation to code data around the centre frequency of 868.3 MHz Data rate can be from 8192 to 16384 kbps.

Outdoor radio frequency signals can be transmitted around 150 m, while in residential areas it drops to 20-30 m. In addition, various signal amplifiers can be used. Each module must be equipped with an antenna.

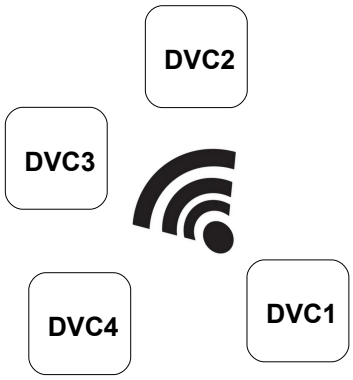

Fig. 38: radio transmission

4. Internet protocol (IP): a way of transferring and connecting devices within a KNX installation that allows for higher speed and a wider possibility of using the device. It uses the same Ethernet cables used to connect a computer to a router or a modem, with the well known RJ45 connector. The protocol used is KNXnet/IP (UDP). The biggest advantage of ip / Ethernet communication is the possibility of access control via VPN (virtual private network) which allows access to the system even when you are not at home and creates additional protection against unwanted access. Another advantage is that the Ethernet cable can exchange every type of digital information: data, video, and audio.

Fig. 39: RJ45 connector and cable for KNX IP

4.3 NET ARCHITECTURE

Line

The minimum KNX net consists in a bus line, starting from a power supply device, and a set of maximum 64 KNX modules connected (pushbutton modules, actuator modules, sensors etc). Since the address with last number set to 0 (i.e. 1.1.0) is reserved for line couplers, the real available addresses are in the range 1 – 63.

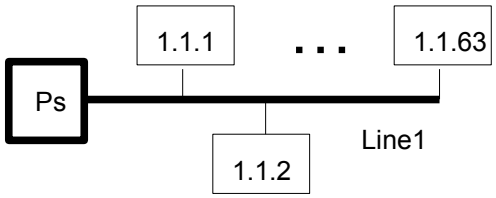

Fig. 40: a simple KNX line

The maximum number of devices is 64, as we said, (including the line coupler, if present), but the real number of elements on the line depends on the power of the selected power supply unit and the consumption of individual elements.

If necessary, a KNX line can be extended to 4 segments, and there can be 64 elements in each segment (4 · 64 = 256, with address from 0 to 255). Each segment must have its own power supply unit.

We need the so-called *line repeaters (LR)* for that.

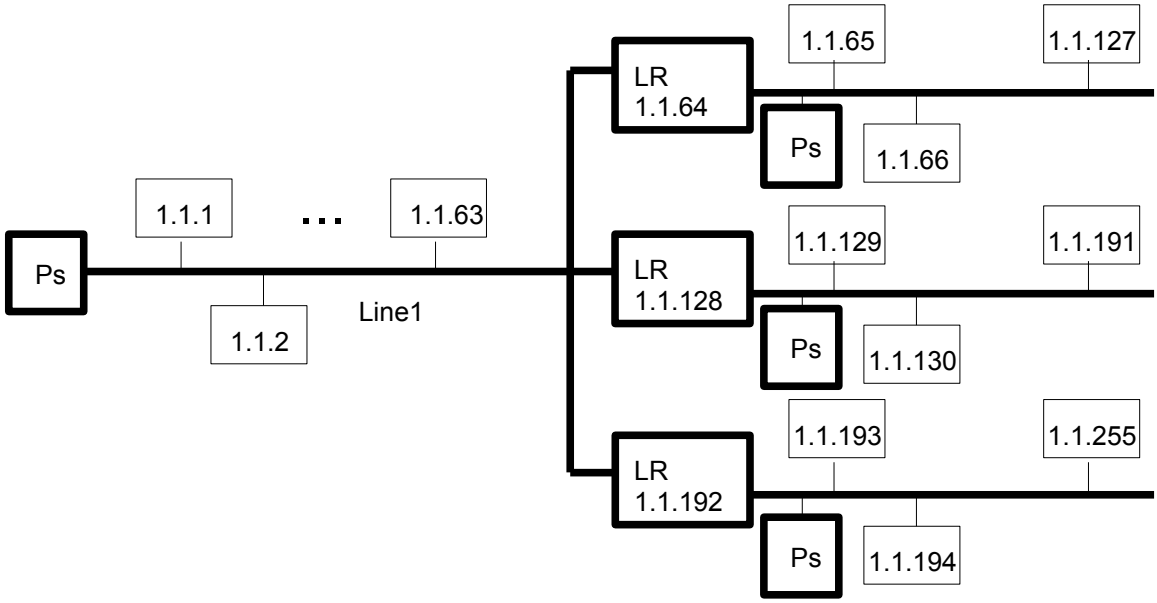

Fig. 41: an extended KNX line

Area

If we need more than one line or if the elements of the KNX installation are connected in a different form, we can connect up to 15 lines to each other via the so-called line couplers (LC).

Such a structure is called an area.

The line that connects all the line couplers is called Main Line.

We can also have up to 64 KNX installation elements on the main line. The maximum number of elements on the main line decreases with each line coupler we have on it.

Each line, even the main line, must have its own power supply.

Line repeaters (LR) must not be used on the main line.

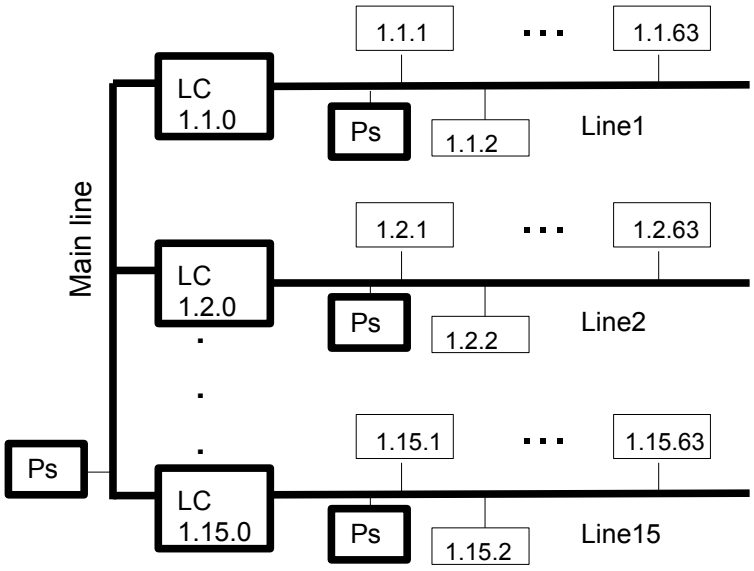

Fig. 42: a KNX area

A complete KNX system

The KNX installation can be increased by connecting up to 15 individual areas to each other via the so-called *area couplers (AC),* obtaining a complete KNX system. The line that connects all the areas is called *backbone*.

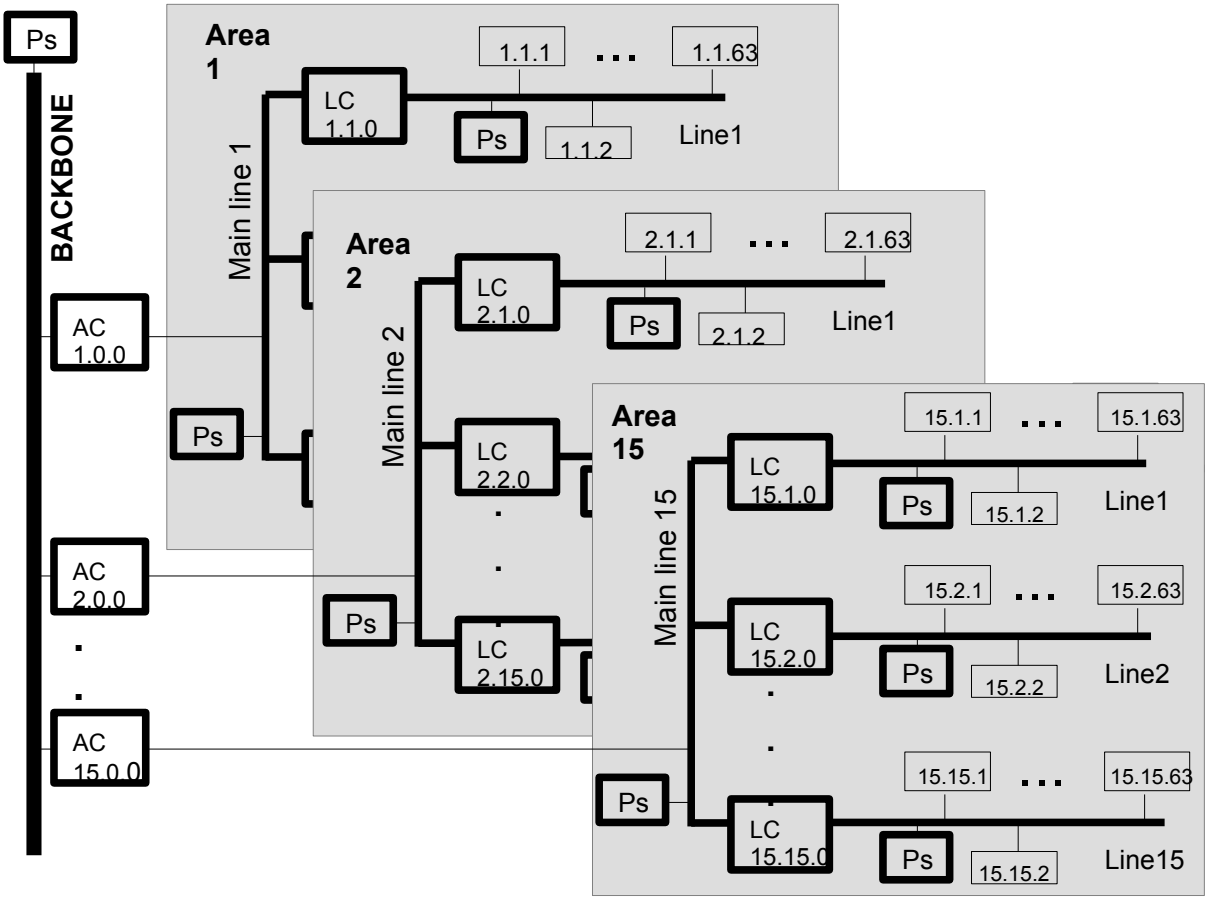

Fig. 43: a full KNX system

All three couplers AC, LC and LR are the same device. How they will work depends only on their location in the KNX installation and the physical address we have assigned to them.
The last number in a line coupler address is always 0, the last two numbers in an area coupler address are always 0.
Couplers are also able to filter, by means of tables, the data they manage, to decide if a command or a sensor information must stay on the same line or must cross the coupler to reach another line /area.

AC and LC send forward only the telegrams written in their filter table, while LR send forward all telegrams.

We can also have up to 64 KNX installation elements on the backbone. The maximum number of elements on the backbone decreases with each area coupler we have on it. In this way, we can have more than 58000 KNX elements interconnected.

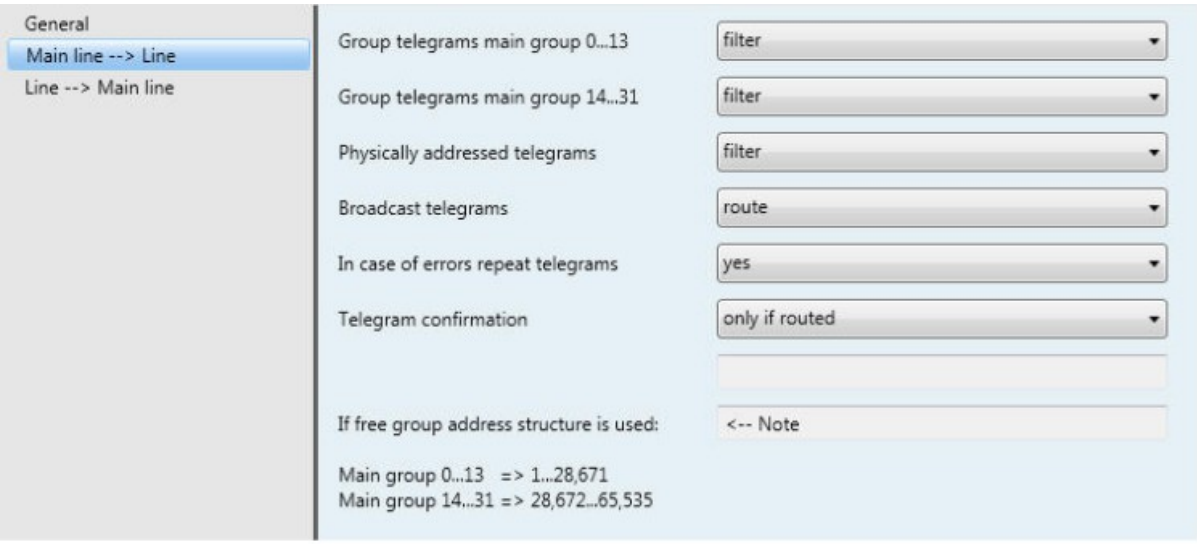

Fig. 44: example of setting a filter table in a coupler device

4.4 TOPOLOGY

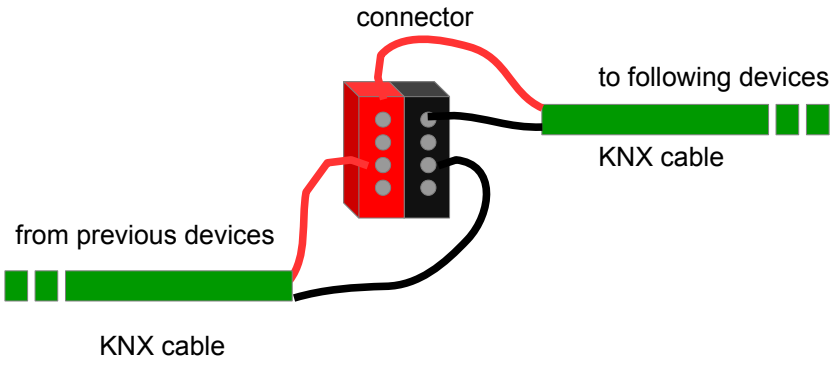

Fig. 45: KNX bus connector

KNX devices are connected to the bus data cable via a component known as bus terminal, that is a plug-in terminal able to accommodate up to four KNX cables.

The way the bus cable is laid inside the conduits and reach all the modules is defined as „topology“.

In a smart home system the topology can be:

- *daisy chain*: every device is connected to two bus cable sections, one entering (coming from the previous device) and one going out of the device (to the following one)

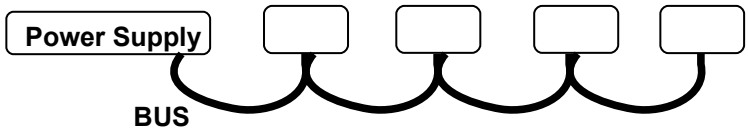

Fig. 46: daisy chain topology

- *star*: devices are directly connected to the power supply unit. Of course is not possible to connect all the devices, since the terminals of the power supply can accomodate only a certain number of conductors.

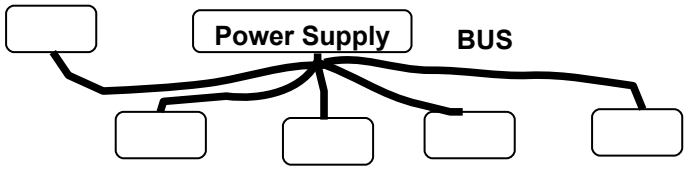

Fig. 47: star topology

- *tree*: is a mix of the previous two topologies. Is the more common.

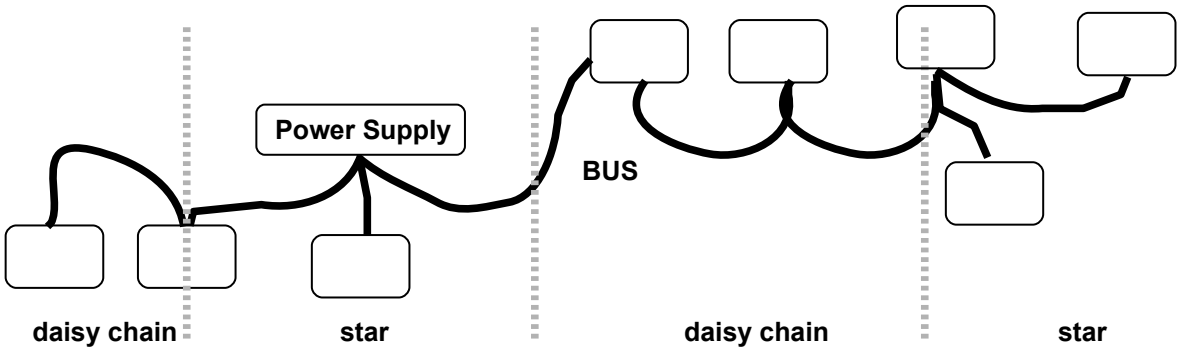

Fig. 48: tree topology

4.5 ADDRESSES

A Konnex system can be very huge and articulated, with many lines and devices.

How to perfectly distinguish one module from the others? How to be sure that a data transmitted from a certain module on a certain line in a certain area is correctly delivered to another specific module that is located on another line and in another area?

The solution to this problem is giving a specific code to every connected device. Every code must be different from all the others, in order not to get confused.

This strategy is similar to the one that distinguishes every house in a street from the others. Since each of them has a specific and individual street number, it is impossible to do a mistake in the mail delivery.
In a generic smart home system, we call this code an “address”.
In the Konnex world there are two types of addresses: individual and group addresses.

Individual (physical) address

In KNX installations, we use physical addresses to address individual elements.
These addresses consist of three numbers, separated by full stops.
A physical address has thus the following form: 8.4.5.
Starting from the left, the first number (8 in the example) is the area number where the module is located, the second one (4 in the example) corresponds to the line where the module is located and the third one (5 in the example) corresponds to the module number on that line.
Since all the data transmitted are digital, each of the three numbers is translated into a bit sequence.
The area and line numbers are coded using 4 bits each, simply because we can have a maximum of 15 lines and of 15 areas, so four bits are sufficient ($2^4 = 16$).
Instead on a line we can have a maximum number of 256, so we need 8 bits to represent all the possible combinations ($2^8 = 256$).
Thus, for example, the physical address 1.1.2 will be translated in:

area [4 bits] – line [4 bits] – element [8 bits → 1 byte]

1.1.2 – area 1, line 1, element 2 (0001–0001–00000010)

If we use a software to configure the KNX system, we need to assign every address to the corresponding KNX module. To do this, with the computer connected to the system bus, we press the programming button located on the KNX element while we perform the software address configuration procedure.
During this process, the LED on the element lights up.

Group address

In a Konnex system every module must have its own and unique address, but it must also know which are the other modules involved in a specific function.
For example, if I want to turn on and off light 1.2.3 from push button 1.2.8, I must virtually “interconnect” these two elements and their addresses.
To do this, a KNX system uses the group addresses.
A group address is a set of two (so called 2 level group address) or three (so called 3 level group address) numbers, separated by slashes.

Group address 0/0/0 is reserved (as a broadcast message) for telegrams for all the elements of the KNX installation.
In case of 3 level group address, a main group can have a number in the range 0 - 31, a middle group in the range 0 - 7 and the sub group in the range 0 – 255.
In case of 2 level group address, a main group can have a number in the range 0 -31 and a sub-group in the range 0 – 2047.
The designer can decide for himself whether to use a 2 or 3 level group address and also how he/she will use individual levels.
Most of the time there is a logic behind this choice: for example one can think to associate main group address to floors, middle group address to functions and third group address to anything else.
Once we get used to a certain way of using group addresses, it is recommended to stay with this way in other projects as well.

It has to be noticed that actuators can belong to multiple group addresses, while sensors can only belong to one group address.

4.6 TELEGRAM

Each change in the installation state (e.g. button pressed) causes the involved bus device to send a signal to the system. This digital signal is a bit sequence that must follow certain specific rules that depend on the so called “protocol” used.
This protocol defines how long is the data transmitted, which is the bit/rate of the transmission, how the information are organized in the bit sequence and so on.
Let's call this bit sequence a “telegram”.
These telegrams consist of information specific both to bus communication and user information (e.g. key state). The overall information of the telegram is packed into groups of 8 logical states – octets or bytes - which in turns are grouped together in fields.
Figure 49 shows the layout of the telegrams by bits.

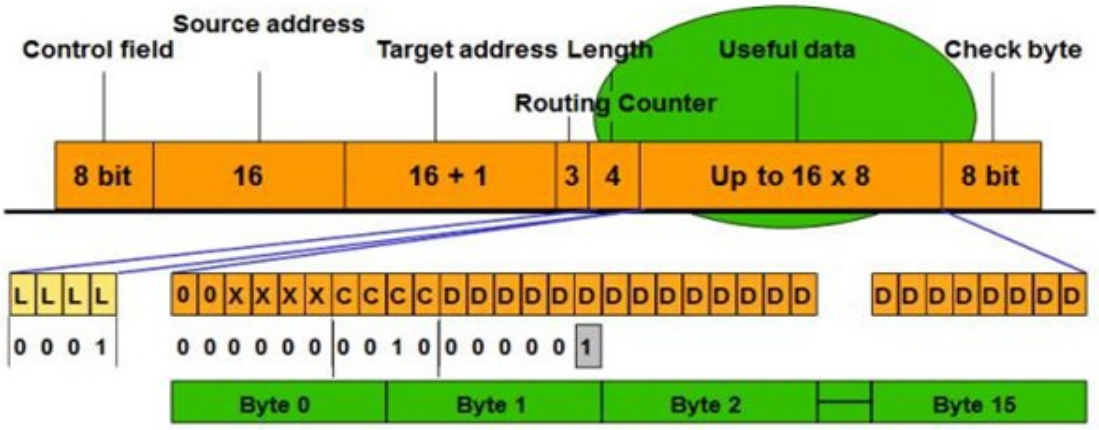

Fig. 49: KNX telegram

In the telegram we distinguish the following fields:

- Control field and check byte (8 + 8 bits) - These fields are necessary to ensure the smooth flow of telegrams. The user receiving the telegram analyzes these fields upon receipt.
- Address field - source and destination address (16 + 17 bits) - the address field contains the address from which the telegram originates and the address to which the telegram is sent.
- User data field (up to 16 x 8 bits) - this field contains the states of the sensor or command to execute, i.e. the information sent to the device

The following happens when transmitting a telegram (for example if one key is pressed):

- the microprocessor detects the closing of the contact using the application hardware
- the microprocessor generates one telegram (containing all the fields) in its memory which is then sent bit by bit over the KNX net
- the telegram sent in this way is “heard” by all the connected devices, but only the module whose address is specified in the telegram as the target address reads the contents of the data field and executes the command located at that place
- CSMA/CA (Carrier Sense Multiple Access /Collision Avoidance) ensures that there is no interference on the bus if two or more devices want to send telegrams at the same time.

In case of simultaneous sending of two telegrams by two different modules, one module takes precedence, while the other aborts its transmission and try to retransmit later.

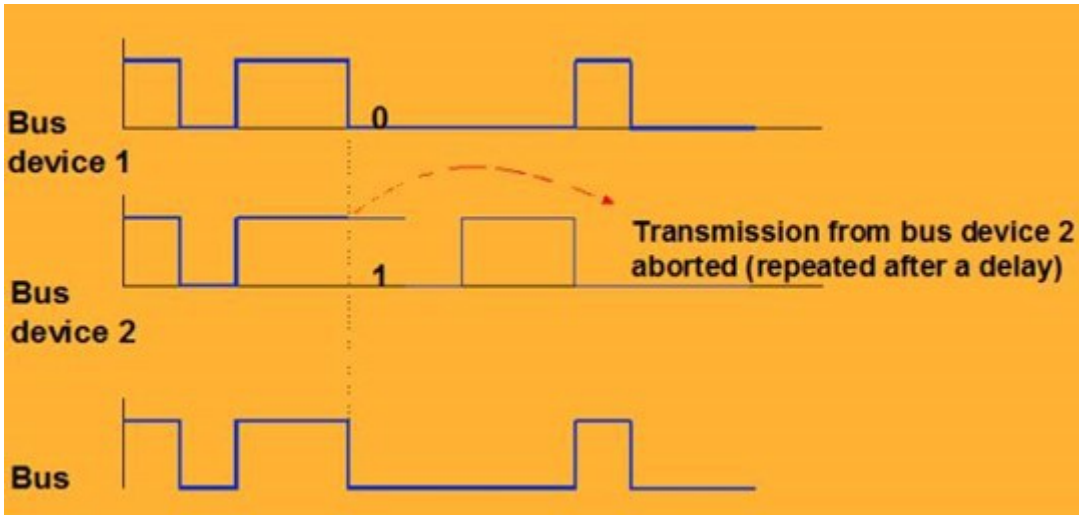

Fig. 50: parallel transmission of 2 telegrams

There are several different types of telegrams, depending whether this telegram is supposed to stay in a line/area or not (maybe it is transmitted from one device on line1 but it has to reach a device on line 9, or a device located in another area).

4.7 PARAMETERIZATION METHODS

KNX installation elements can be parameterized in the following ways:

- E-MODE (easy mode) – parameterization is performed without the use of a computer
- A-MODE (automatic mode) – parameterization is performed automatically when connecting the element (very rare)
- S-MODE – parameterization is performed using a computer with a specific program called ETS (Engineering Tool Software).

In practice is almost always used parameterization using computer with the help of the ETS program.

4.8 ETS

ETS is adapted to different types of users, from beginners to experienced users, and it is now released in its fifth version (ETS5).
Therefore, there are several versions of ETS5:

- ETS5 Demo – free of charge, to work with up to 5 elements of KNX installation (0 €)
- ETS5 Lite – small projects, 20 elements of KNX installation (150 €)
- ETS5 Professional – unlimited number of KNX installation element (1000 €)

A newer version of the ETS, ETS6, will be launched shortly.

On the official website of the KNX organization (https://www.knx.org/knx-en/index.php) can be found a useful online classroom. It's called e-Campus. When you complete the tasks prepared there and achieve a result that is better than 80%, you get a discount of 50 € when purchasing the ETS5-Lite program and a certificate that you have completed e-learning, which looks like the picture shown in figure 51.

Fig. 51: certificate for succcessful completion of eCampus training

Alternatively, you can also access free online trainings called Live Webminars.

In addition, the KNX organization also offers other types of seminars, for basic and advanced audience, which are taking place at more than 350 locations across Europe. They are not free. The price of an individual seminar is around 1300 € and lasts 5 days, the last day is a theoretical and practical exam. At the end of a successfully passed exam, you will receive a certificate that can only be issued by a company that offers such training.

4.9 CHANNELS, ITEMS AND PARAMETERS

Every module can have several different configurations and parameters. For example an actuator could be set in such a way to instantly switch on or off its load, or to switch it with a delay, or to make it blinking.

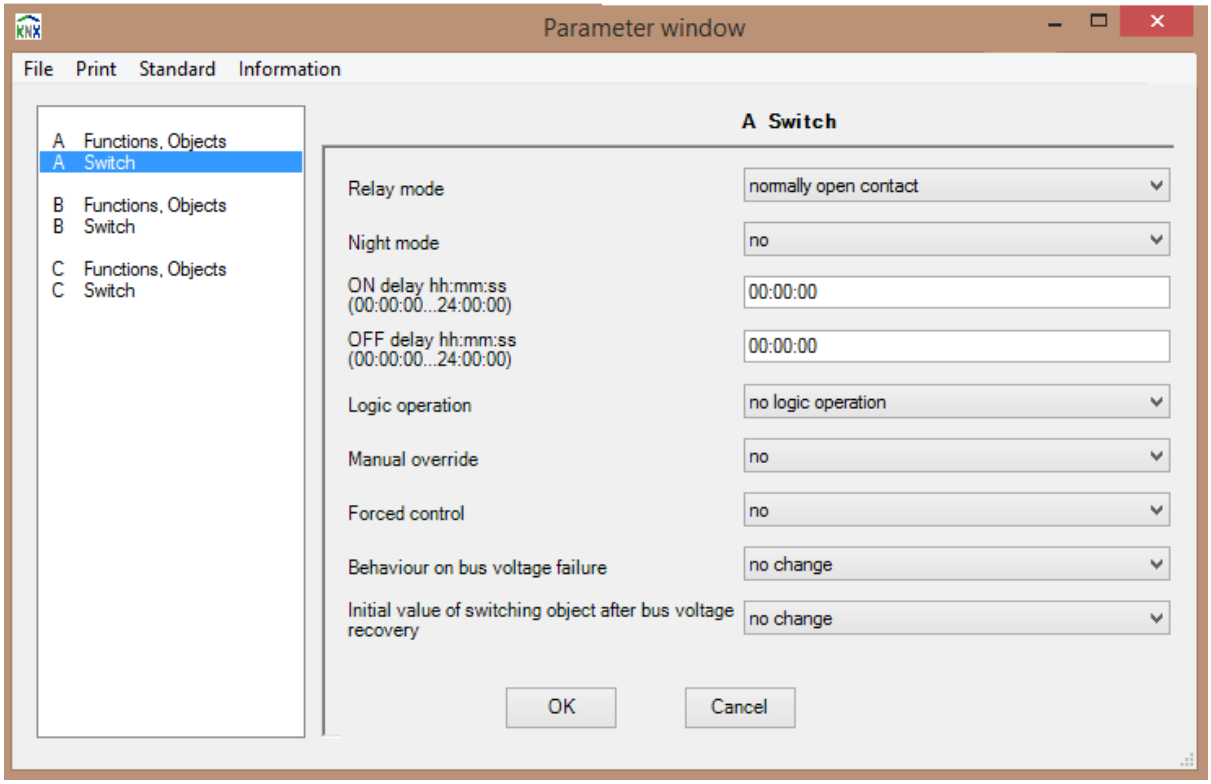

Fig. 52: parameters of a KNX switch module

For example, in figure 52, we can see that it is possible to set a numeric value for „On delay“ or for „OFF delay“, and to set the behaviour of the module after a bus voltage recovery.
Another thing that we have to consider is that, most of the time, a device is a multi input or multi output module. For example we have double or triple push button modules, quadruple actuators and so on.
When a KNX device can perform many actions on different inputs or outputs, we distinguish these different actions in „items“ and the different inputs and outputs in „channels“. For example, in a double push button module, channel A can be the left button and channel B the right button.

Every manufacturer assigns a number to all the items, that in turn are associated to specific functions on specific inputs or outputs.
Let's take a look at figure 53, related to the items of a binary output module (a binary output is an actuator module able to switch on and off a load, while a binary input is an input module able to generate two commands for an actuator, that are on or off).

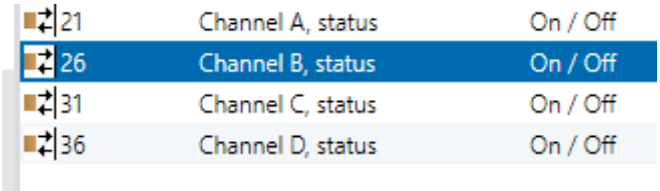

Fig. 53: channels and items of a KNX module

In this case item 21 is associated to the function of switching channel A (the first output), item 26 is associated to the function of switching channel B (the second output), item 31 is associated to the function of switching channel C (the third output) and item 36 is associated to the function of switching channel D (the fourth output).
What we put in a group address are not only the individual addresses of the modules involved in the function, but their specific items. In this way we can have a very accurate behaviour, selecting which input channel acts on which output channel, with which specific function and with which specific parameters.

4.10 EXAMPLE OF A SIMPLE KNX SYSTEM

Let us assume that a small KNX system consists of the following elements:

1. power supply unit (29V DC)
2. KNX double push button
3. KNX single actuator for lamp
4. BUS cable
5. power cable (230 V)

If we want to draw a scheme of this small set of devices we must know that there are not official symbols recognized all around the world as electrical symbols of smart home system components.
Anyway we can often find the following figures:

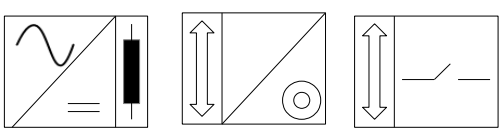

Fig. 54: symbols for power supply, button and actuator

The scheme will be thus as follows:

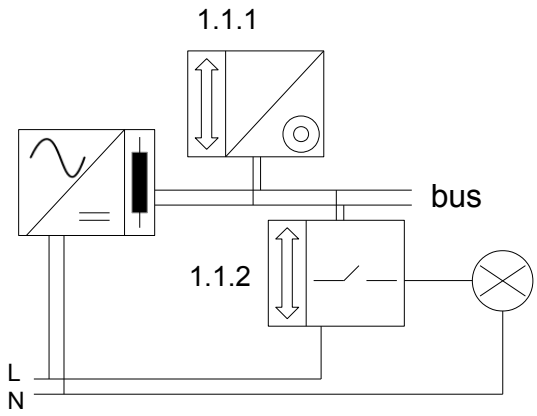

Fig. 55: electrical scheme of the KNX system

The power supply unit transforms 230Vac into the DC bus voltage.
The smart button is connected only to the bus, the smart actuator both to the bus and the mains cable.
Let's suppose we are on line 1 in area1.
We have to assign an individual address to every module (except the power supply unit, that does not have an address), then we have to assign a group address to the devices involved in a specific function.
If this specific function is performing on and off of a lamp, we have two involved modules: 1.1.1 and 1.1.2. One is the command, the other is the actuator.
Let's suppose we have chosen the group 3/4/7 that involves 1.1.1 and 1.1.2, and that items of 1.1.1 are:

- 5 channel A alternated on/off
- 6 channel A only on
- 7 channel A only off
- 8 channel B alternated on/off
- 9 channel B only on
- 10 channel B only off

while items of 1.1.2 are:

- 30 switching on/off
- 31 flashing
- 32 switch off

We can create for example two groups: the first one (3/4/7) allows us to click on the left push button obtaining the light to be turned on, then clicking again on the same push button obtaining the light to be turned off (and so on). Another group (for example 3/4/8) allows us to click on the right push button obtaining the same light only to turn off (we can not switch on that light from the right push button).

If we want to obtain this, we have to insert item 5 of 1.1.1 and item 30 of 1.1.2 in group 3/4/7, and item 10 of 1.1.1 and item 32 of 1.1.2 in group 3/4/8.
To summarize:
group 3/4/7:

- item 5 of 1.1.1
- item 30 of 1.1.2

group 3/4/8:

- item 10 of 1.1.1
- item 32 of 1.1.2

Only affter having properly configured individual and group addresses and parameters with the ETS software, we have to load the application program into the switch and the actuator, in order to have a working system.

The designer must therefore carry out the following steps with the help of the ETS program:

- determine **physical addresses** of individual elements (to identify elements in the KNX installation)
- set parameters (**parameterize**) and application program for sensors and actuators
- specify **group addresses** (to connect sensor and actuator functions)

After making the above settings, the installation in the picture above will work, for the first address group, as follows:

- when the left button on the device with physical address 1.1.1 is pressed, it sends a telegram containing the group address 3/4/7 with the value "1"
- this telegram is received by all the devices
- only elements with the same group address send a confirmation telegram on receipt of the telegram and "read" the sent value and respond accordingly. In the above example, the switching actuator with physical address 1.1.2 closes the contact (relay).

5 AN ETS EXERCISE

Open ETS5 software and create a new project clicking on the green cross.

Set the communication medium of the backbone (TP, IP), of the rest of the net (TP, RF, IP, PL) and the group address style (two or three levels).

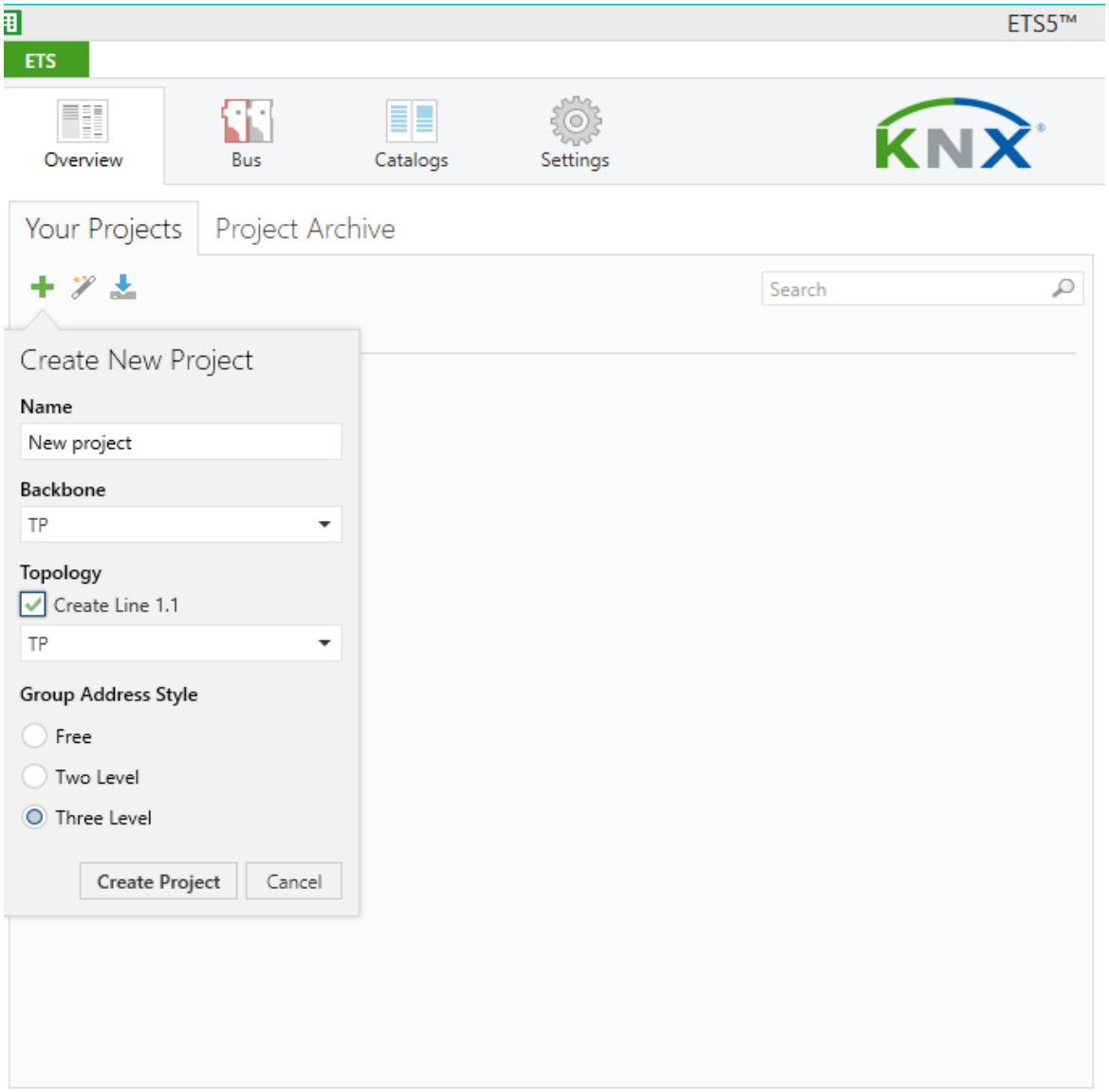

Fig. 56: main ETS5 window

The following screen will appear.

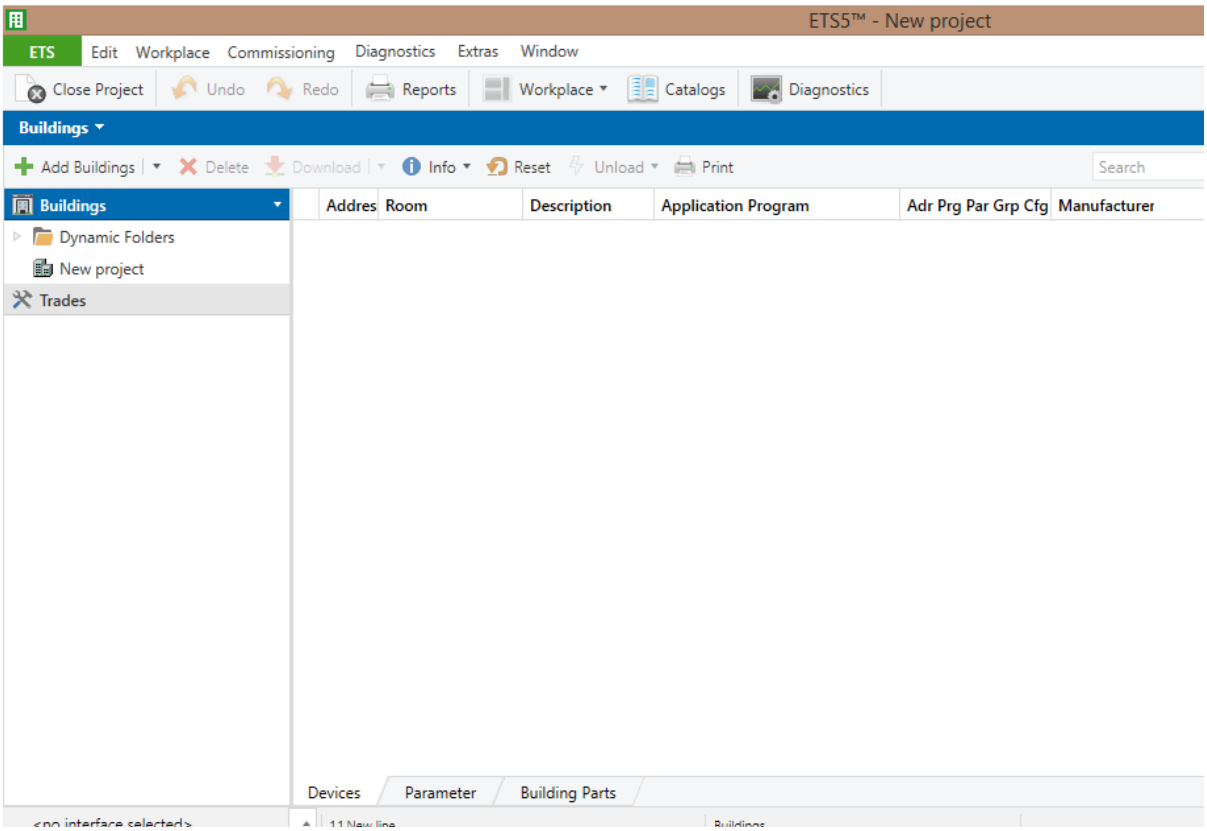

Fig. 57: creation of an ETS building structure

Right click on „Buildings“ and select Add --> Floors

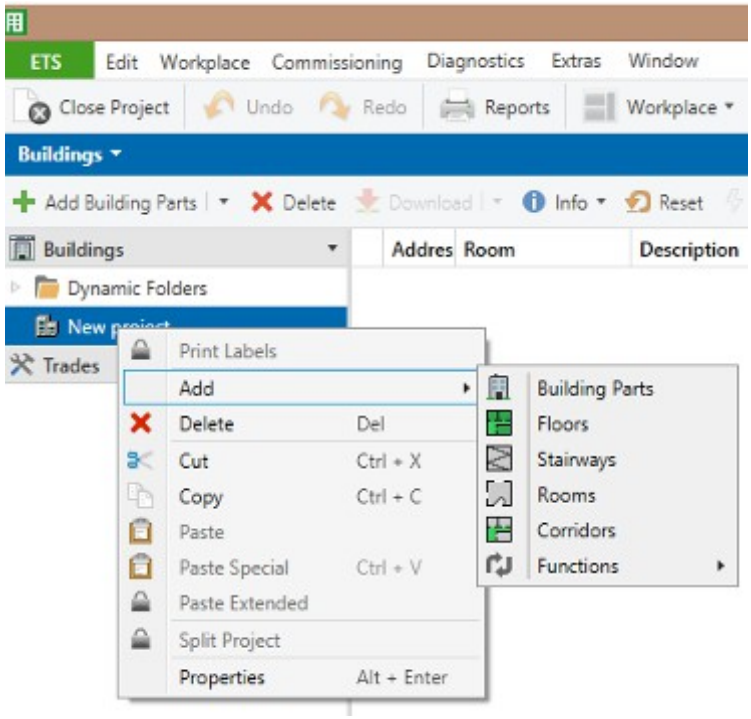

Fig. 58: adding building elements

Add floor1.

Then right click on floor1 and add four Rooms called bath room, bed room, kitchen and utility room.

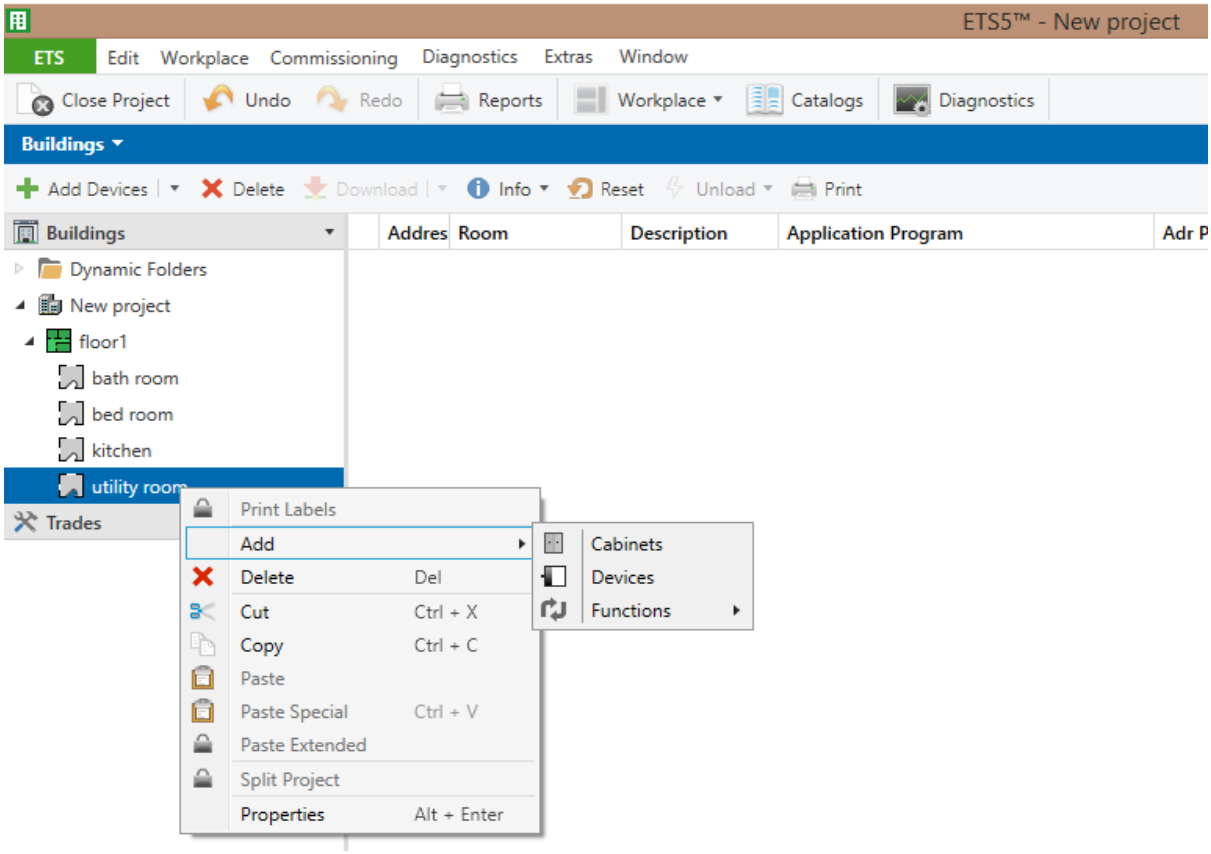

Fig. 59: adding cabinets

Then right click on utility room and select Add --> Cabinets.

Once we have defined floors, rooms and cabinets, it's time to insert devices into the cabinets.

If it is the first time that we use the ETS5 software, maybe we still have to import a database of objects.

Since there are many KNX manufacturers, every one of them has its own product database.

Let's assume we are using Siemens.

On the Siemens website we can find the ETS5 product database.

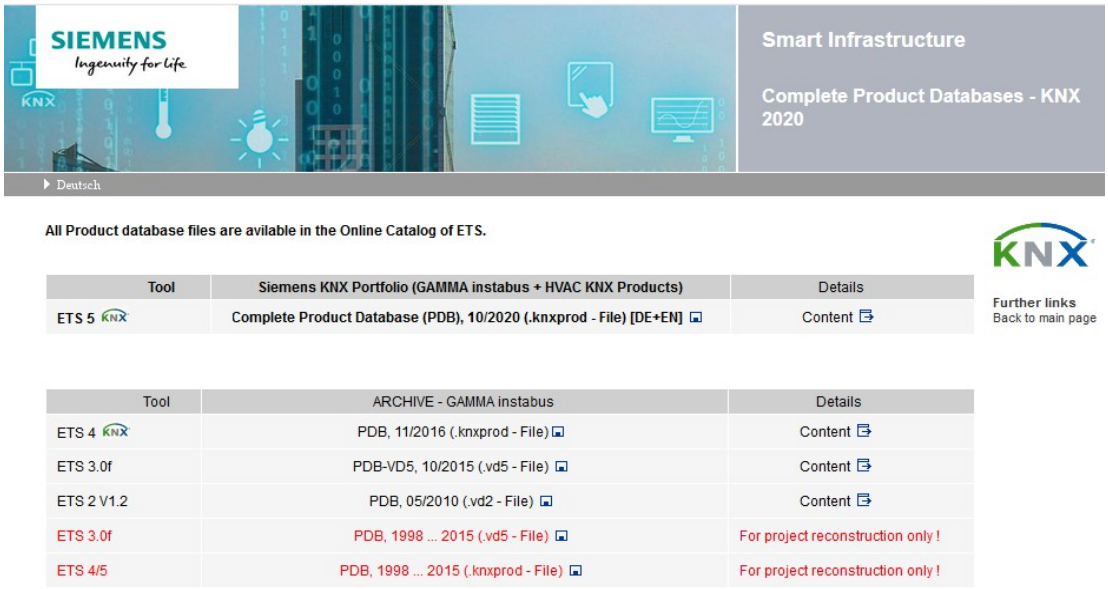

Fig. 60: Siemens KNX database product web page

We have to download it and to import it inside the ETS5 software.

To import a product database in ETS5 we have to click on the Catalog icon and then on the Import icon.

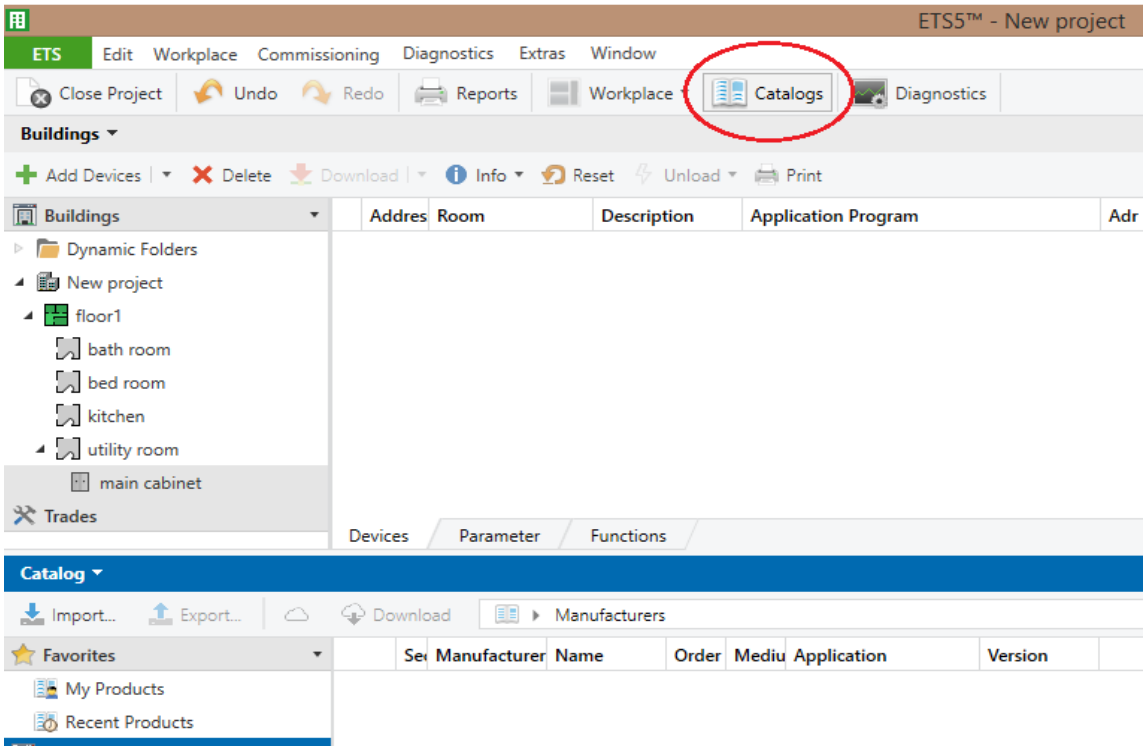

Fig. 61: how to import a catalog

Then we have to find, on our computer, the downloaded file of the catalog.

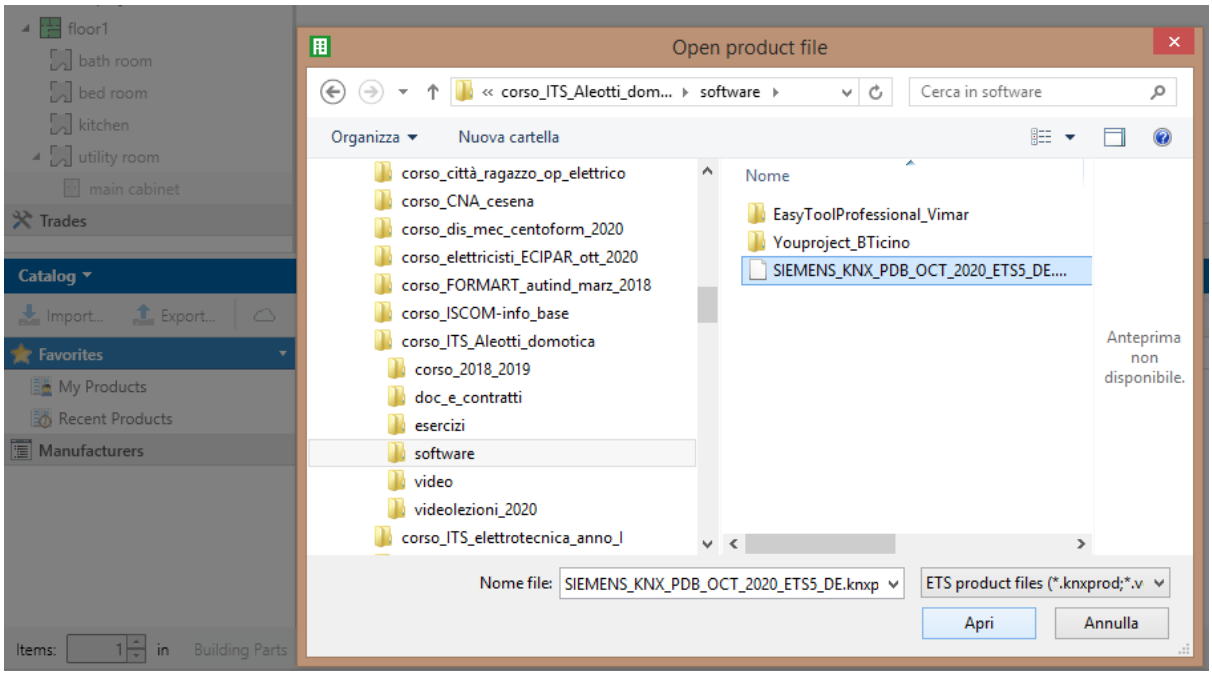

Fig. 62: selecting the catalog file

We can decide to import a specific set of devices or the whole catalog

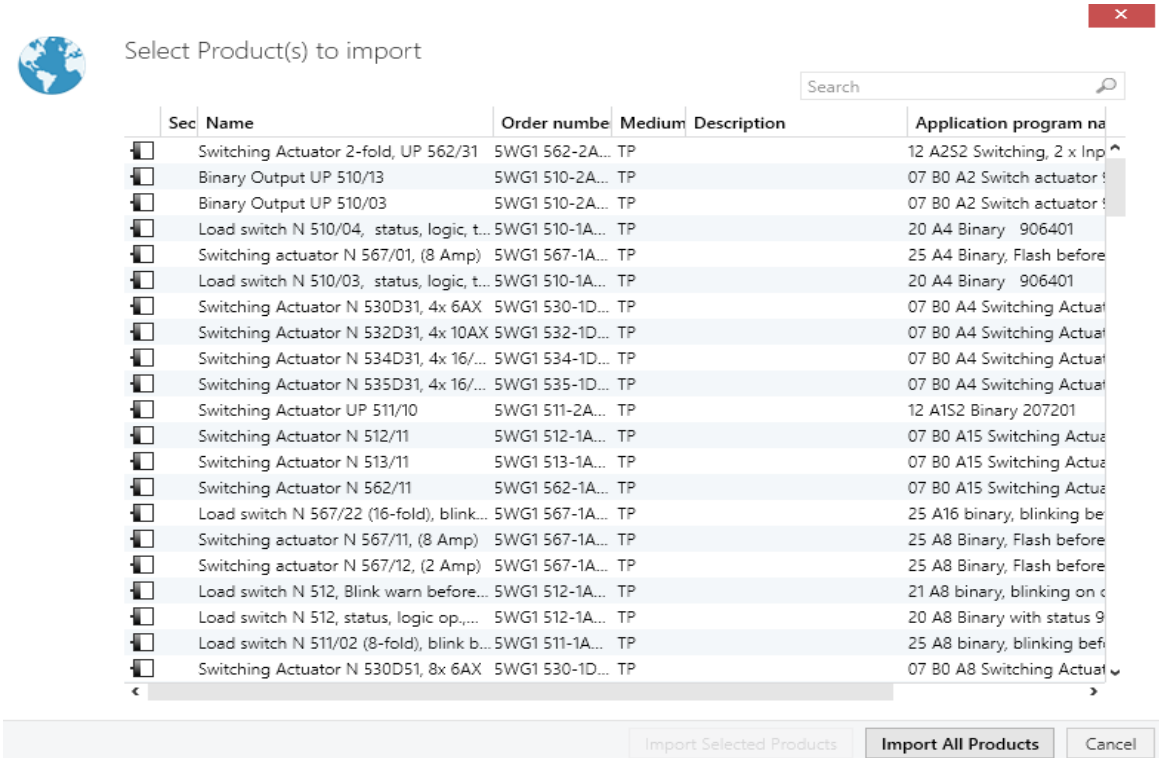

Fig. 63 selecting the product to be imported

If the import session is successful, a window reports it.

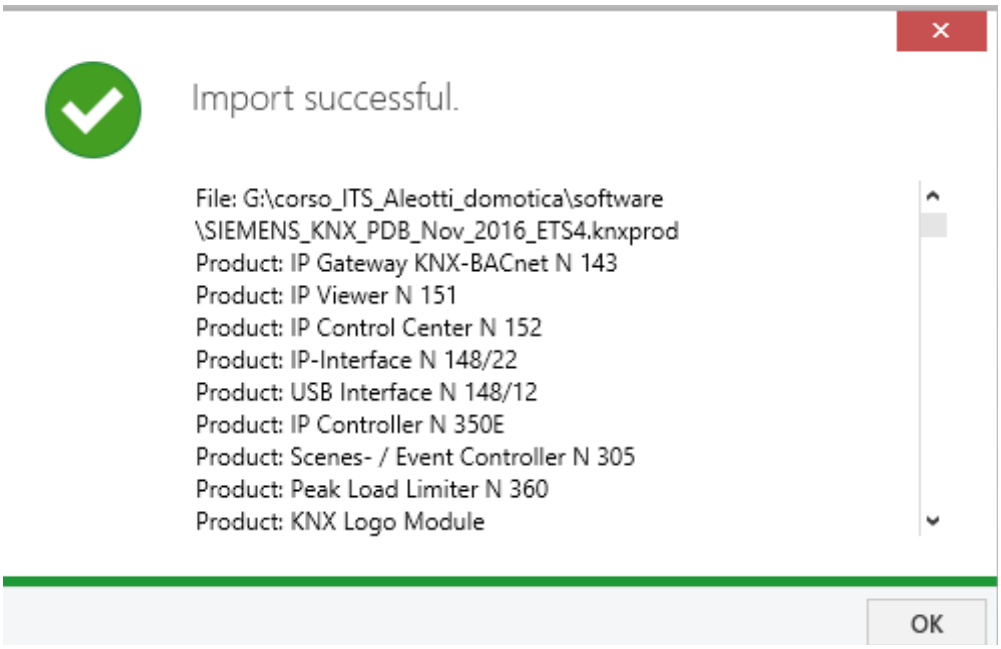

Fig. 64: product database import successfull

Now we can come back to our project, right click on the cabinet and select Add --> Devices

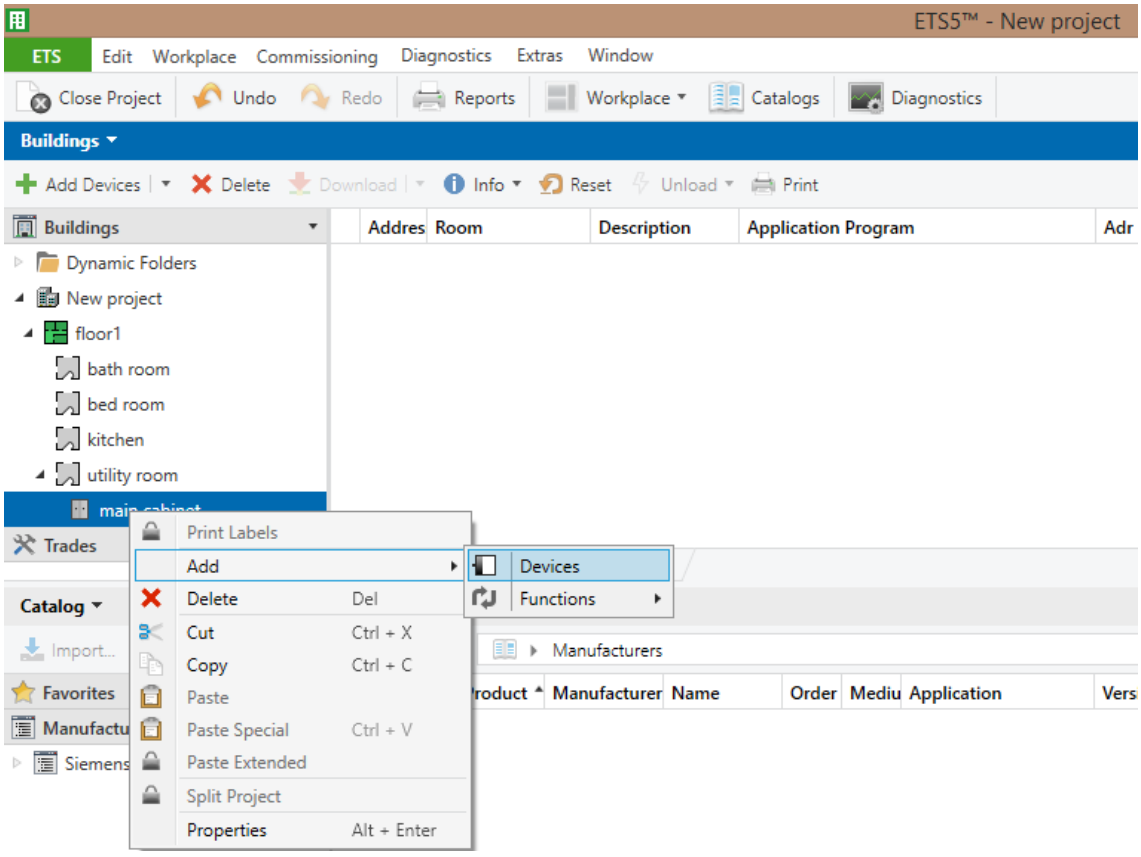

Fig. 65: adding KNX devices

From the Catalog we can add for example a simple binary output module.

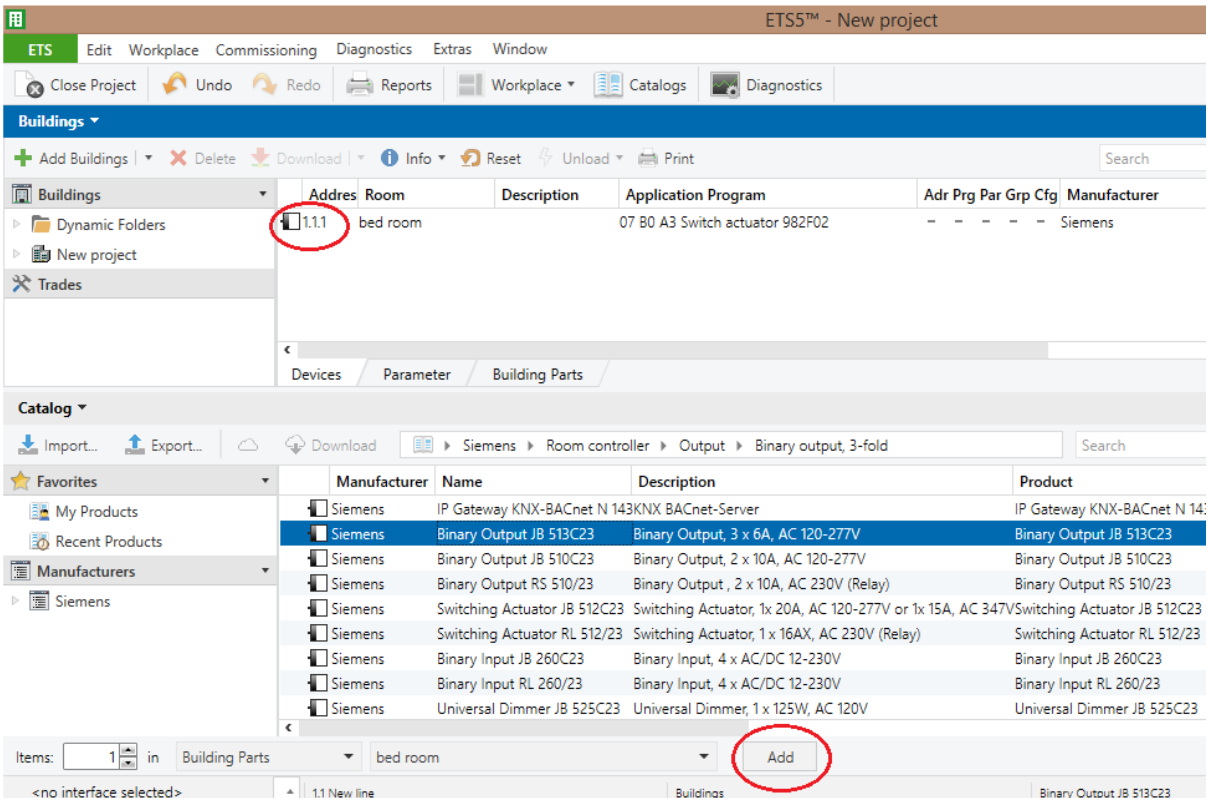

Fig. 66: adding a binary output module

The software automatically gives to the module the address 1.1.1

Now from the catalog let's add also a binary input module.

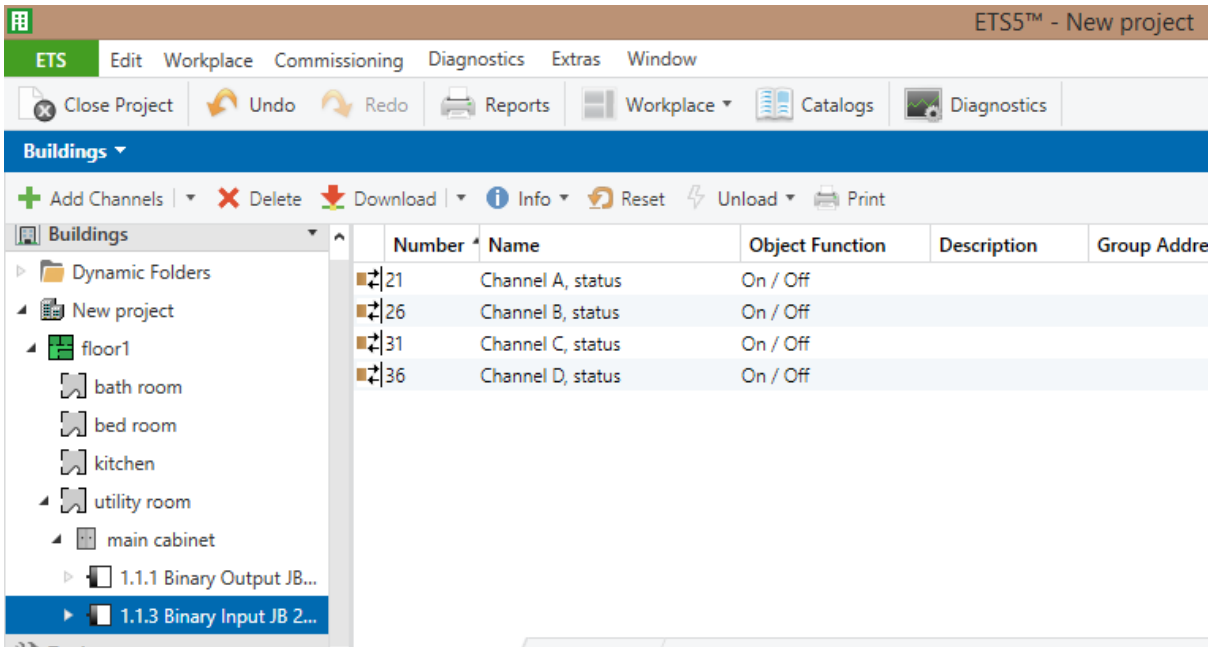

Fig. 67: adding a binary input module

Now that we have two devices, we can create a group.

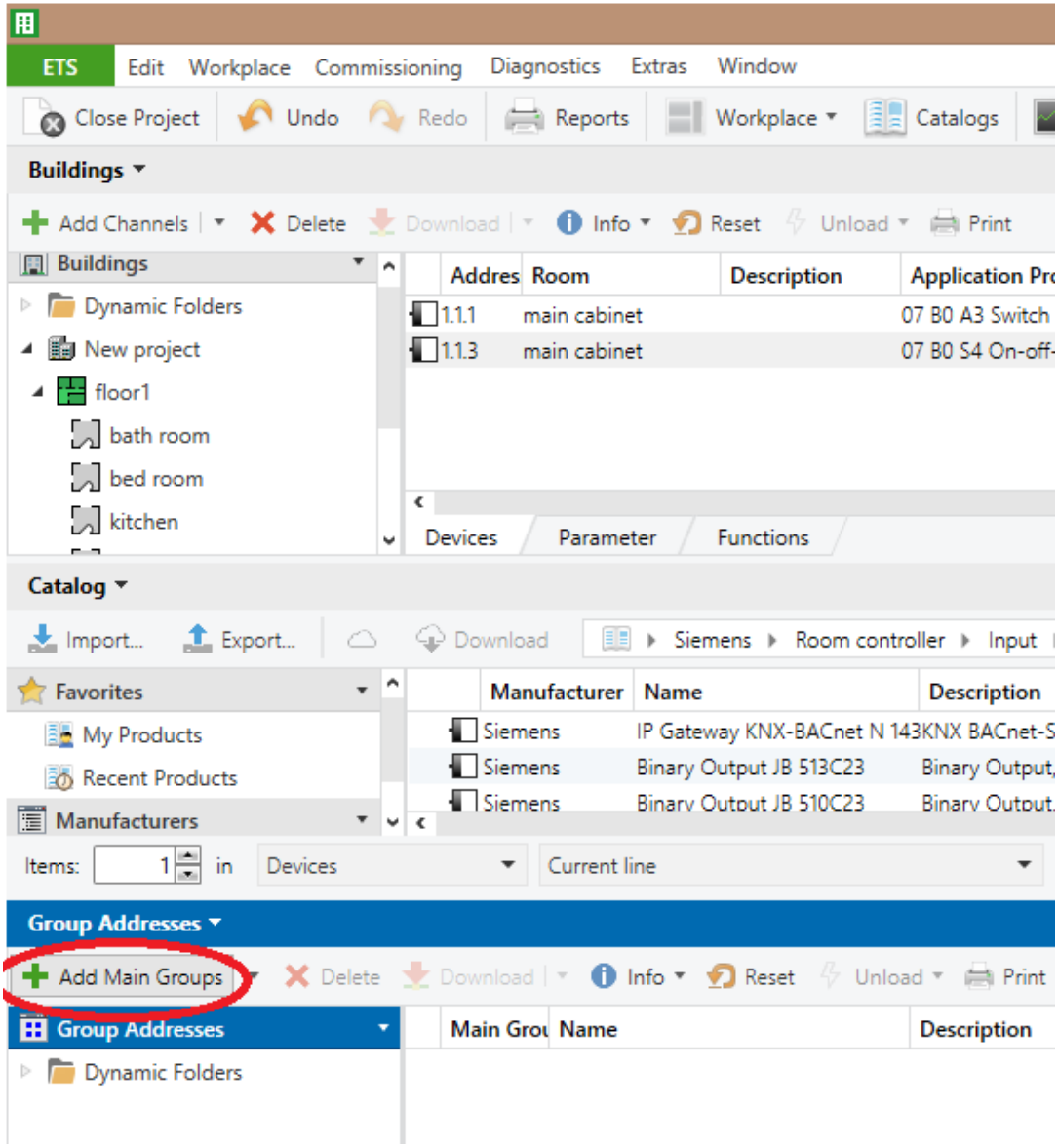

Fig. 68: adding groups

Click on „Add Main Groups“ , create a new group and call it „light“.

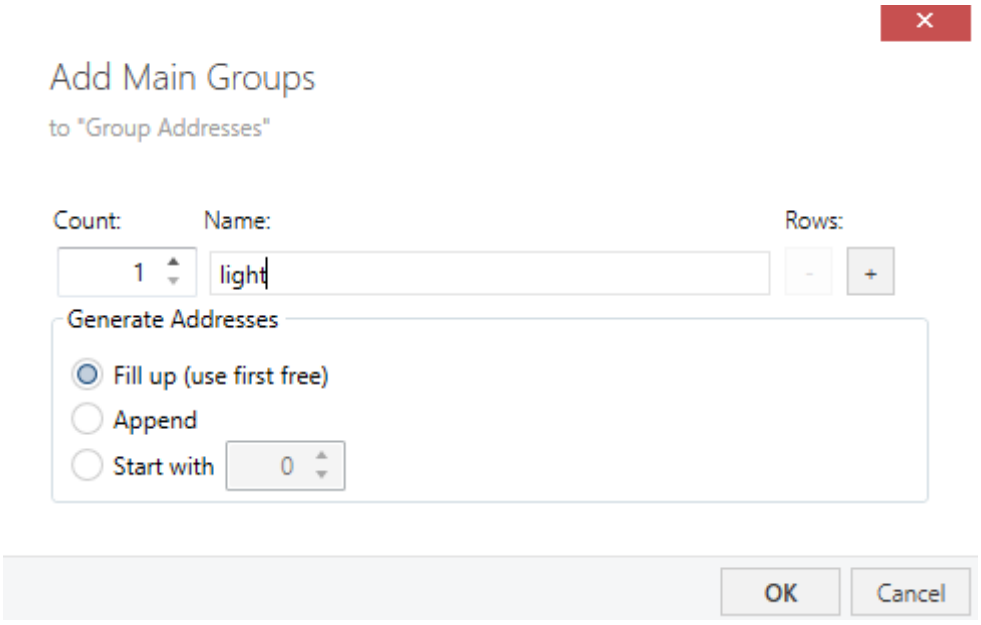

Fig. 69: giving the name to a new group

Now, selecting the just created main group, we can create a middle group.

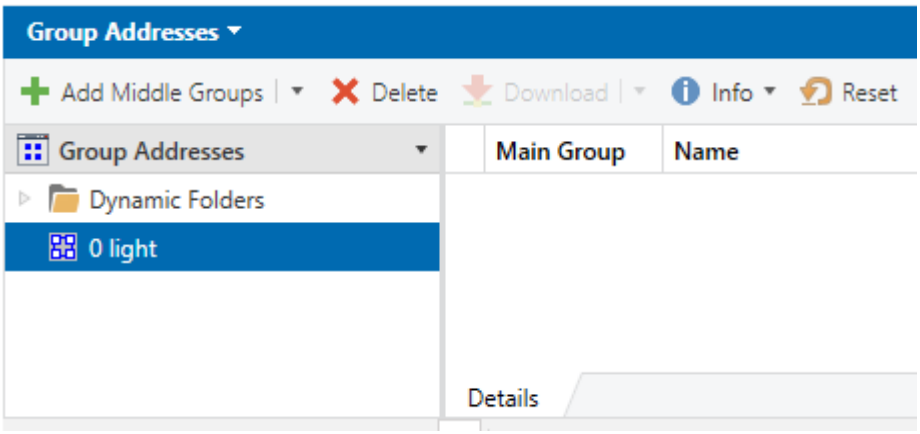

Fig. 70: adding middle groups

Click on „Add Middle Groups“, create a new one and call it „1 floor light“.

Now, selecting the just created middle group, we can create a last group where we will insert the devices addresses.

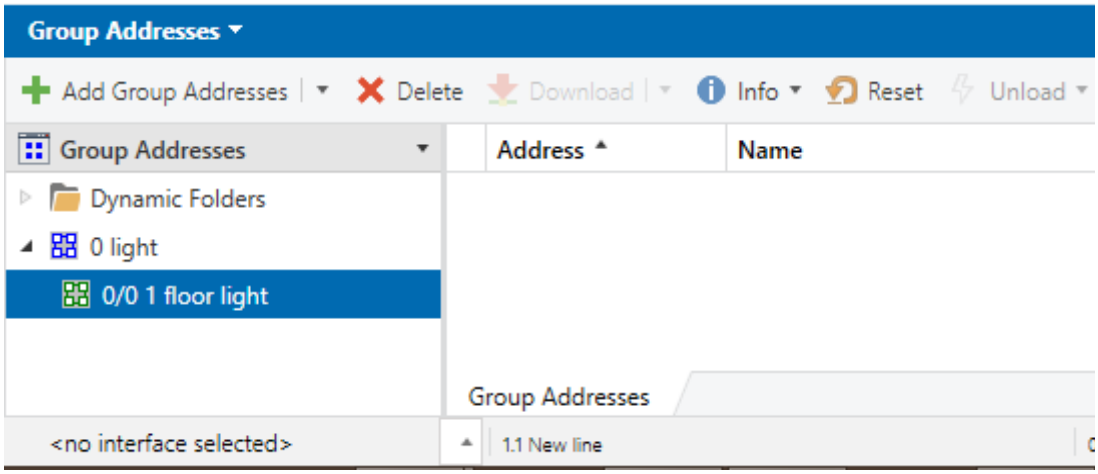

Fig. 71: adding sub groups

Click on „Add Group Addresses“, create a new one and call it „door light“.

Now we can select item 5 of 1.1.1 (the switching on the first output A) and drag&drop it inside the 0/0/1 group window.

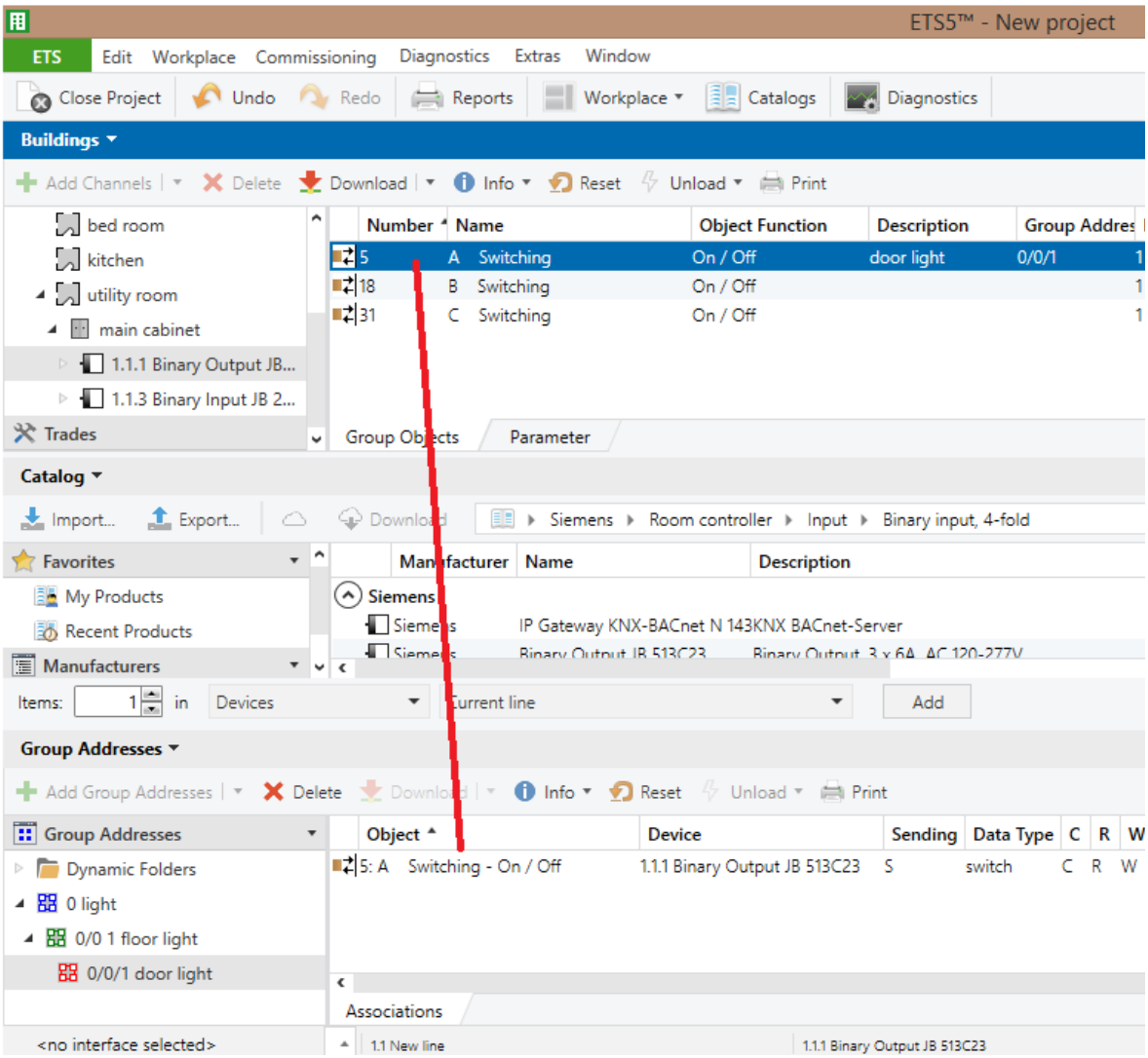

Fig. 72: drag&drop of item 5, module 1.1.1

We can do the same thing with item 26 of the binary input module 1.1.3 (see figure 73).

We have created a group. This group will perform the following function: when the second push button (channel B) is pressed, the first binary output (channel A) will be switched on.

We can continue inserting all the devices and creating all the groups that we need.

After having created all the groups that we need, we have to download our application to the hardware devices.

To do this we have to select Commissioning --> Download and to select the proper function we want to perform (see figure 74).

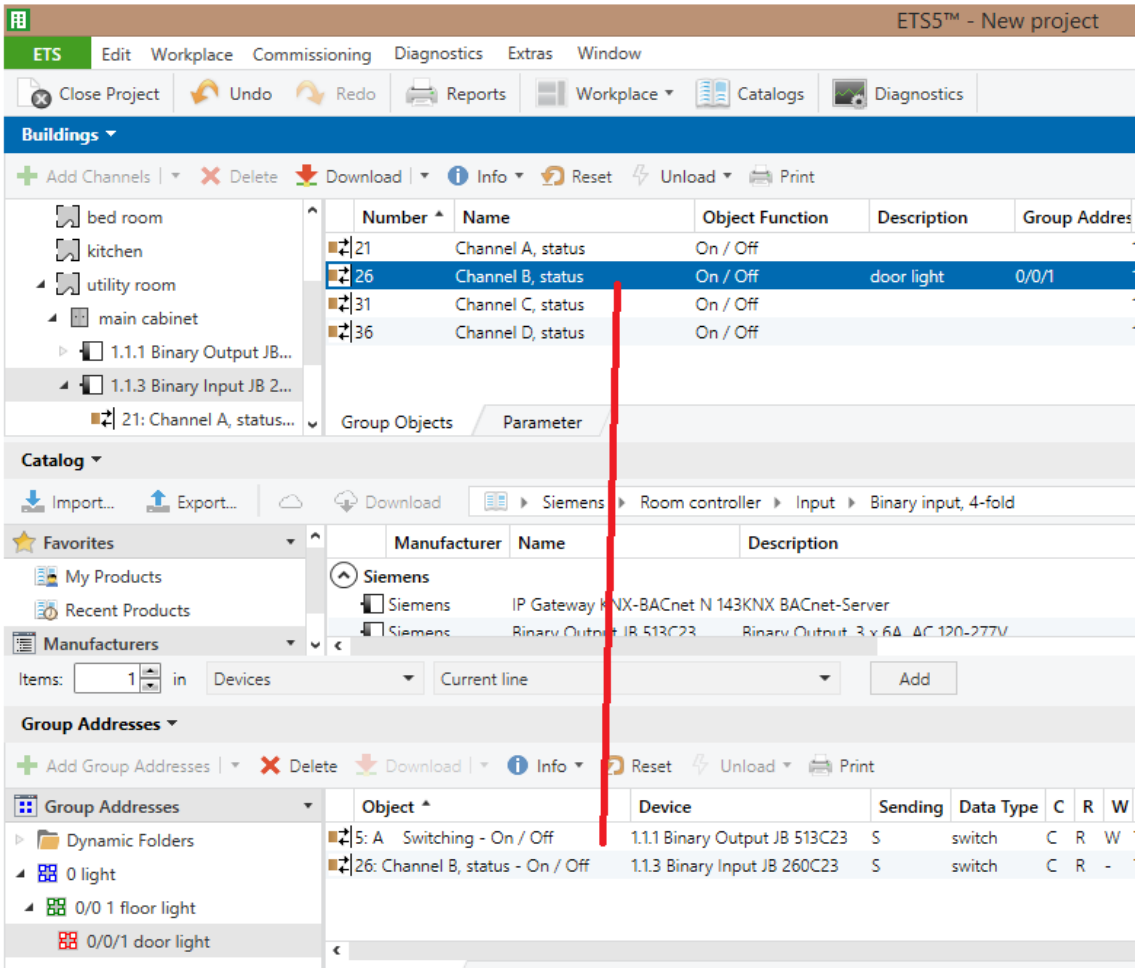

Fig. 73: drag&drop of item 26, module 1.1.3

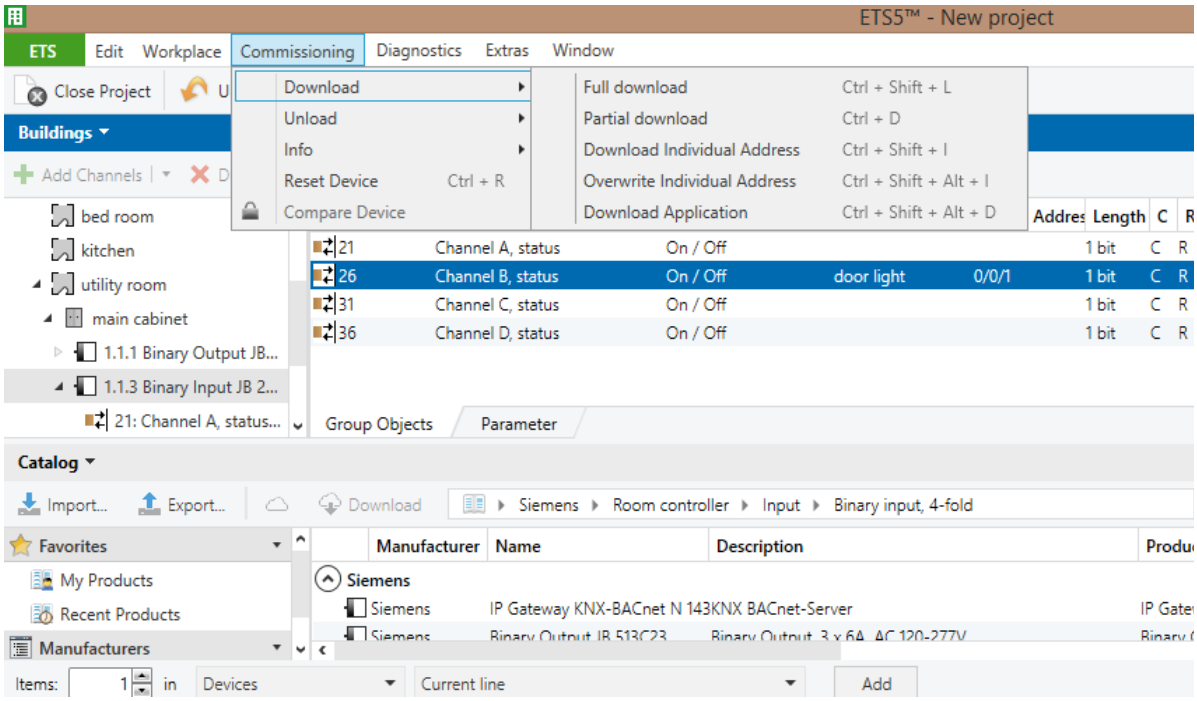

Fig. 74: downloading the KNX configuration to the system

6 MANAGEMENT OF A SMART HOME SYSTEM ORDER

Every electrical designer sticks to his or her established way of working, which he or she believes is best for him or her.
One of the possible ways is the one illustrated below.
It consists of four phases:

- PHASE 1 – Project making
- PHASE 2 – Electrical cabinet
- PHASE 3 – Switches
- PHASE 4 – Startup

Each phase can be split into subphases.

Phase 1: Project making

- Identify the wishes and requirements of the investor
- Project design
- Confirmation of the design from the investor
- Installation of cables and devices in the building

To create a project you need:

- building plan (preferably in AutoCAD format) of all rooms with marked electrical sockets (for 230V, TV, computer, phone etc), lights, blinds, radiators, underfloor heating, switches and so on
- the power and function for each lamp (on/off, dim) indicated in the plan
- location, power and purpose of use of single and three-phase sockets that will be powered or operated via KNX system (underfloor heating, mirror heating, access heating to the building, fans, kitchen appliances, stove, air conditioning ...)
- possible location of electrical cabinets, ideally somewhere in the middle of the building (in the wardrobe, under the stairs ...) and the size of the cabinet (if it is one, you need a space with the size of an ordinary door, more or less)

- contact details of the architect and persons in charge of other areas (swimming pool, heating, ventilation, blinds, air conditioning, alarm system, audio, video, telephone, computer)
- connection power of the whole building (type of system, dimensions of the power supply cable)

The project includes:

- building plan with marked electrical circuits of lighting, sockets, blinds, switches ...
- description of the method of laying electrical installations (special features)
- description of the control systems used in the building for lighting, heating, ventilation, air conditioning, floor heating, external stairs, driveways, entrance doors ...
- description of control systems used in the building for garage doors, blinds ...
- description of the control systems used in the building for the alarm system, telephone, video, audio and computer network
- plans of electrical installations and electrical cabinets
- information on the length and cross-section of the used cables

Phase 2: Electrical cabinet

- Selection and ordering of electrical cabinet
- Installation of elements in the cabinet
- Wiring the elements in the cabinet

The electrical cabinet is the center of the electrical installation in/from which all electrical cables are routed. From it we distribute electricity to sockets, lights and other electrical devices. The KNX electrical cabinet contains:

- **main switch** for disconnecting the building from the main power supply
- in larger buildings - a **fire protection switch** (the switch is located at the entrance of the building), which switches off all circuits except the specified ones
- **voltage presence indicator** - which signals the presence or failure of any phase
- **short-circuit protection** - one or three-phase circuit breakers are installed in each circuit for protection against short-circuits and current overloads
- **indirect contact protection** - RCCB switches for protection against earth contacts
- surge protection - surge arresters
- **KNX elements** - power supply, binary inputs, outputs, analog inputs, outputs, switch actuators, blind actuators, heating actuators, LCD touch screens, communication interfaces ...
- **collector of protective wires** - to which we connect all protective wires

- **collector of neutral wires** - to which we connect all neutral wires
- **terminal blocks** - for connecting phase conductors to devices

Fig. 75: residual current circuit breaker

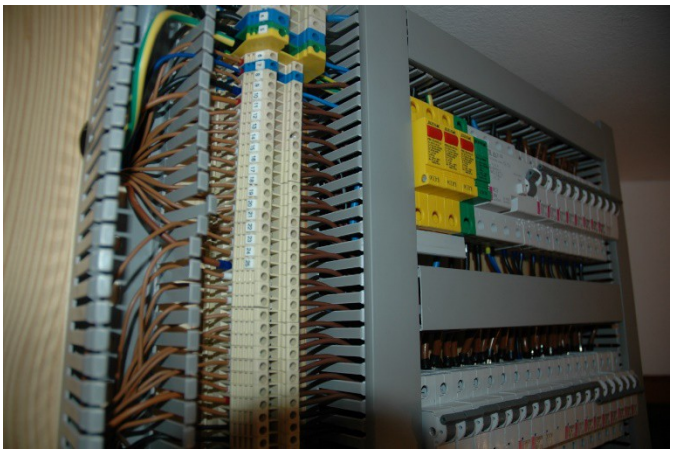

Fig. 76: a wired cabinet

Phase 3: Switches

- Choice of switches
- Ordering the switches
- Defining functions and programming the switches
- Installation of switches and lamps

The switches must match your rooms aesthetically and functionally. All manufacturers of KNX equipment make their own switches of several types.
In case you can not replace your old switches with smart switches, you can use an interface that converts a simple on/off ordinary switch into a KNX switch, connected to the bus cable.

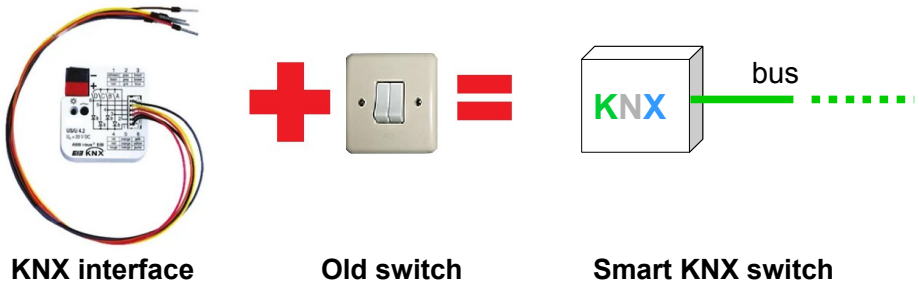

Fig. 77: KNX interface for standard switches

This type of interface is commonly referred as "*spider*".
The most important decision (besides the aesthetic appearance) is the choice of switches according to what they have to allow us.

Here are just a few of the usual ones:

- switching lights and sockets on and off
- switching the lights on and off and changing the luminous flux – dimming
- blinds operation
- opening and closing garage doors, entrance doors
- opening and closing roof windows
- dialing scenes
- turn off all lights

If we remember, a scene is a set of command generated on more than one actuator due to a specific event (the click on a pushbutton, a certain time of the day, a weather event etc).
Here are some common examples of scenes:

- **scenes**: visiting, dinner, watching TV, listening to music, reading, resting, dating ...
- **sleep**: turn off all lights, lower all blinds, turn on the alarm system ...
- **leaving the room**: turn off all lights in the room
- **departure from home**: turn off all lights, turn on the alarm, switch the heating mode to economy mode ...
- **going on holiday**: switching off all lights, switching off all unnecessary sockets and devices, switching on the simulation of presence, switching on the alarm system, switching on the garden watering ...
- **lowering and raising all blinds**
- **turn off all exterior lights** ...

In a smart house you can control almost anything you want, but most often lighting, ventilation, heating, air conditioning, humidifier, blinds, curtains, awnings, driveways, garage doors, front doors, windows, skylights, heating external stairs, driveways path, gutter defrost, alarm system ...

For each room (e.g. living room) you must first decide what you want to control or operate and then choose a switch (or more switches) with so many keys and built-in functions that allows you to do what you want. Do not forget also those devices in the adjacent rooms or outside the house that you possibly want to operate from this (living) room.

Phase 4: Startup

- Determining the correct operation according to the requirements (wishes) of the investor
- Fine-tune system operation

If you want to easily and quickly start and check the operation of the manufactured KNX installation system, you must first know the system well.
It is best to write everything down accurately. You can help yourself with the following questions:

- Which key on the switch controls which device and how?
- What should happen when calling individual scenes?
- What functions do you want to control with the remote control?
- What features do you want to manage with your phone and tablet?
- What information do you want to send from the KNX system to your smartphone?
- Which sensors affect which devices? - glass breakage sensor on alarm, window opening sensor on heating, motion sensor on light or alarm, water spill sensor on water valve and message on smartphone ...
- Should the KNX system also respond to external influences and if so, which ones and which devices should it be affected by? - temperature, rain, humidity, wind, windows, blinds, heating, air conditioning, ventilation ...
- What information should be displayed on the color LCD touch screen?

7 HOW TO MANAGE CUSTOMERS

When selling a smart home system we must pay attention to what we offer to our customers. We often present them all the possibilities offered by the technology, but sometimes we forget that for most homeowners, even a small improvement in the operation of their building means a lot.

The most satisfied are usually those customers who have a built-in basic smart home system that meets all their requirements. Maybe it's just lighting control and a simple upgrade from one thermostat for the whole house to multiple thermostats for each room separately. Most of them do not want to have an automated whole home, but are satisfied with a small improvement in performance.

7.1 PROBLEM DEFINITION

When we start talking about the use of modern technology in buildings, one of the possible procedures is to define the problem and then solve it. Let's look at two practical examples.

A young couple expecting a child is building a new house. When talking to them, mention that you can set the switches so that they will turn the lights on to different brightness levels depending on the time of day, and not as with classic lights, where most lamps light up at full first. Then present a practical example such as e.g. controlling of the child in the middle of the night. We can avoid to turn on the lights and stumble on one of the toys we didn't put away, or we can turn on the light and wake the child up completely. For example, we can show to our customers which are the advantages of lighting with different levels of illumination at different times of the day. It is important that we do not offer a solution yet. This comes later.

Another example is the case of a restorer renovating a bar. Since the bar is a business, the owners are primarily aware and interested in the price of renovation. For example we can present to the owner at least one of the advantages offered by light regulation, e.g. reducing the light to achieve a more romantic atmosphere in the bar, making visitors feel more comfortable. If this is not possible, they will probably not return to the bar often and there will also be fewer or lower tips. Higher tips, however, mean that employees will work even better, which means better business for the bar.

Once you know the problem of your customers, ask them which positive consequences there will be if a smart home system solved this problem. You have still not offered a solution, but they are already considering the positive results that their cooperation with you can bring.

These are two very simple examples, but in practice, clients usually have a lot of problems, so look for them and listening to them as much as possible. If you manage to solve these problems, both you and the customers have won.

7.2 SEARCH FOR FINANCIAL RESOURSES

Usually customers do not have a sense of how much a smart system will cost them. A direct response can trigger a negative response. By defining the problems you can solve and by asking them how much they would be willing to pay to solve their problems, the customers gain an understanding of the value you can offer them. Now the only question that follows is how much they can afford to spend.

We still haven't offered them solutions, so it's important to take their problems to the next step, where we present solutions and a price proposal. We need to remind them of the problems and positive results that solutions can bring. In this way, we have more chances to carry out the business.

If we take the time to examine your customers' wishes, we will find out more quickly and easily what kind of building automation they need and come to a realistic price that gives satisfaction to both sides. With this, you present yourself as a trusted designer who doesn’t just want to sell a service. This is how you stand out from the competition, as customers remember you for exactly how you dealt with their wishes. Many times, they opt for the provider that gains their trust, rather than the provider that has the lowest price.

So if you have managed to get a deal, you must now offer a solution as well.
A smart home system essentially provides flexibility, resilience and scalability, so we need to keep that in mind well, when we approach to design.

If we opt for one line per floor and one divider per floor, this allows for flexibility in possible later system upgrades. In the event of a power outage, this outage would only affect this floor. So it’s always good to have some reserves.
Why do not install a smart switch with more keys instead of fewer (although we don't need them at the moment because the customer will only be using lighting)? We could use these additional keys we have already installed when later upgrading the blinds and heating control system. It is not a significant added amount of money, but it can reduce problems and costs of further developments.
This strategy is often applied: if in a room we need three push buttons, we install a module with four pushbuttons. The price for the customer is more or less the same (at the most a few extra euros) but the advantage in case of future changes is remarkable.

Fig. 78 : multi-keys switch

7.3 HOW TO CHOOSE THE RIGHT PRODUCTS

Fig. 79: analog output module, shutter actuator and KNX IP gateway

Before making the installation, it is good to think about the points mentioned below.

In most cases, during the process of determining the requirements and wishes of the client, we determined which elements are necessary for the installation.

There are many manufacturers of KNX elements. They have very similar technical characteristics, but not precisely the same.

How to decide which one to use?

The simplest (or most difficult) is to choose switches or sensors. Some manufacturers produce a very large range of switch shapes, colors and materials. The choice of shape and design (and thus the manufacturer) of the switches can be left to the client, while you have to decide on the other KNX components.

Which aspects do you have to consider to select the most appropriate KNX manufacturer?

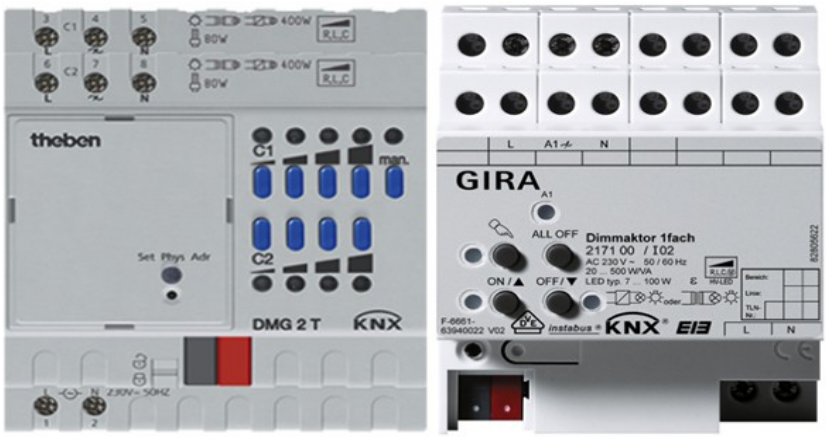

Fig. 80: dimming actuator

Price: if we want to save the clients money, the most important thing is to find the cheapest provider of KNX elements. Customers can quickly find a manufacturer online with a cheaper price.
But remember that, for you as a designer, it is not only the purchase price and your margin that are important, but, or especially, the manufacturer's support for you, as the designer.

Reliability: the client needs to be reminded of the proverb “more money, more music”. This does not mean that there are not a few cheaper manufacturers on the market, but maybe they are not the most suitable or reliable ones.

Experience: if you change the manufacturer from project to project, you are doing more work to yourself. If you have achieved good results and have good experience with the elements of a manufacturer, then use only their products, except in specific cases such as if this manufacturer does not offer some item that you need to fulfill the wishes of the customer.

Advantages of the company name: it may happen that, as a designer, a certain company offers you a better price or support, or the client has explicitly requested that company. In this case, you will have to decide what is more important, price, performance or something else.

Documentation: documentation is also an important factor, as it is important not only that the documentation contains all the necessary information, but also that the documentation is understandably written. Think about what data you need and what you don't (simple electrical wiring diagrams, ...).

8 INSTALLATION AND START-UP

As a designer of a KNX installation, you can (only) hope that the electrician followed all the plans and instructions to the letter and laid all the wires and cables in accordance with them, which he also marked accordingly. It is important also that he has installed all the switches and sensors in the right rooms and in the right places, because otherwise the pre-parameterized elements will turn on the wrong loads.
Improperly laid cables, missing cables, unmarked cables are precisely those situations that we want to avoid.

Fig. 81: correctly marked terminals in the distribution box

Properly marked conductors and terminals are a prerequisite for proper operation. However, the assembly and commissioning of a KNX installation can be performed in various ways.

8.1 PARAMETERIZATION AND START-UP AT THE INSTALLATION SITE

Many clients and/or non-technical persons expect to see how the installation will be parameterized and run on the facility itself. They think they will see how every KNX element will be connected to the bus, built into the switchboard and parameterized at the installation site, one by one.
This way of working is very annoying and takes a lot of time, as it is necessary to do all these steps for each KNX element, which means a lot of running around the object and connecting to it with a laptop in hand, going from room to room, from floor to floor and so on.
It is not professional and thus it is not recommended.

8.2 PARAMETERIZATION AND START-UP AT OFFICE

If you want to avoid running around the object from element to element, you must unpack each module at your office, connect it to your (temporary) BUS cable (line), assign to it an individual address, parameterize it, make connections to other KNX elements via group addresses, and upload everything using ETS in peace at office, rather than from a laptop at construction site. By doing so, you have greatly shortened your work on the facility itself. You can also test the operation of the entire installation at office and not on the construction site.

A great advantage of this way of working is that we separate programming from the installation itself. If everything works as it should at office, then the installation should be free of malfunctionings.

In reality, projects require programming in both office and facility, especially since projects are subject to change during implementation, thereby adding elements and changing performance. The more tasks we can do at office, the better is.

8.3 ERRORS AT FIRST START-UP

It would be a great thing if, at the end of the installation, the system perfectly worked according to the wishes and requirements of the client. But most of the time it happens that some problems arise when you first run the plant.
What are the most common problems and what are the steps to test and fix these problems?

Problems with elements that do not work or reset themselves: first check that the bus voltage is present in the KNX element by pressing the programming button on it. If not, this may mean that the BUS cable is broken or the element does not have a good enough connection to the BUS cable.

If several elements do not work, this may mean that the connection is bad somewhere, and therefore all subsequent devices have lost the BUS power supply.

Check that the power supply is not overloaded, as shown by the indicator on the front of the power supply itself.

Do the devices at the end of the BUS line work once and not the second time? Use a voltmeter to check the voltage and recalculate the current required for KNX elements to operate. 64 elements on one line is the maximum, but if any of the devices needs a current greater than 10

mA, this number can decrease. Also, make sure that you do not exceed the maximum allowable distances between items.

Fig. 82: BUS voltage measurement on KNX device

Check the voltage and current if the KNX elements at the end of the BUS lines are not working as they should.

Unusual bus behaviour and non-working knx elements: did you make a loop with the BUS cable? Are you sure you didn't?
If the KNX elements do not respond to telegrams, check the topology and check that you have downloaded the last valid filter tables in them when using line interfaces.
Verify that you are using the latest product database files or those that match the items for KNX elements.

These are just a few examples that you may encounter when you first turn on the system.

9 CLOSURE AND DELIVERY TO A CLIENT

Once you've resolved any installation and programming issues, check the following steps:

- check that all wiring are arranged and properly marked
- double check that everything is working as planned
- complete all documentation and add a printed report using the ETS program
- back up the project

At this point, the customers will start using their installation and start asking you for changes in its operation.
This can mean easily and quickly changing the parameters of some keys, but you must consider that there will always be "just one more change" and that taking into account all the ideas of the client may cause the operation of the installation to be too complicated to use.
In any case it is important to distinguish between the original project and the additional changes required by your customers, so to be able to draw the line and determine when the project ended and when these changes require a new payment. Therefore, it is necessary to have an open conversation with the clients when the project is completed. It is best to test and verify the operation together with them and then sign a statement that the system is operating as specified at the beginning of the project.

9.1 LATER SUPPORT

Every smart home system also needs service, just like your car.
What is covered in servicing can vary from provider to provider and depends on both the project and the finances. The service should include:

- visit at the transition from summer to winter to control the operation of heating/cooling
- enabling remote programming and parameterization
- changing thresholds and parameters (temperatures, timings and so on)
- the possibility of replacing the expired KNX element with a new one
- 24-hour help by phone and guaranteed response time
- minor software upgrades for KNX elements
- larger software upgrades for KNX elements that offer greater functionality
- settings of new mobile remote control devices (internet)

It is best to offer the client one year of system maintenance already in the original project. In this way, you enable a high level of servicing without the problems mentioned in the previous section.

It is true, however, that there is a big difference between servicing a system that has been ordered and manufactured, and making subsequent changes that will improve the usability and efficiency of the system.
Be sure to specify exactly what is covered by the offered one-year servicing and what is not, so to be able to issue a new invoice to the client when needed, in order to be always professional, to give value to your work but not to ask for a double payment when it is not necessary.

10 CONCLUSION

We have now reached the end of this guide.

You have learnt a lot about smart home systems.

We have talked in general about net architectures, modules, topologies, communication media, addressing, softwares, and then we have focused on Konnex, a very famous, robust and reliable smart home system standard.

You have now all the bases to draft a project, being able to consider every aspect that must be taken into account, from the first phase of designing and talking with the customers to the last part related to maintenance and further developments.

Every project is different, you have to be aware of that all the time. But they all contain steps that are the same for everyone. If you take the time at the beginning of the project to precisely define the task and produce accurate documentation, all further steps of the project will be easier and the project itself will be more manageable.

Of course it is not mandatory for you to use Konnex: many other smart home system manufacturers exist all over the world, with good products and services offered.

The important thing is that you accurately study and know the technical details of the technology you have selected, with its advantegas and disadvantages, and that you always offer a clear, honest and valuable service to your customers.

APPENDIX

- Lonworks

LonWorks was engineered to be both a data protocol and an electrical standard for digital communications. It is used not only in the building automation sector, but also street lighting, transportation, utility, and industrial automation companies have adopted the platform as the basis for their products and services.
The platform is built on a protocol created by Echelon Corporation for networking devices over media such as twisted pair, powerlines, fiber optics, and RF.
In building control, LON technology is used primarily for the decentralized processing of automation functions in room automation.
You can use different processors to scale the system's performance and capability, which means that LON can also be used at the automation level. This level can carry out monitoring, controlling and regulating functions for building services such as heating and ventilation systems. The focus of using LON technology at the automation level is not to decentralize individual functions, but to provide a standardized integrated bus system.

Components of LonWorks system

LONWORKS technology consists of a vast number of interconnected elements, comprising hardware components, software applications and organizational structures, as shown in fig 83.

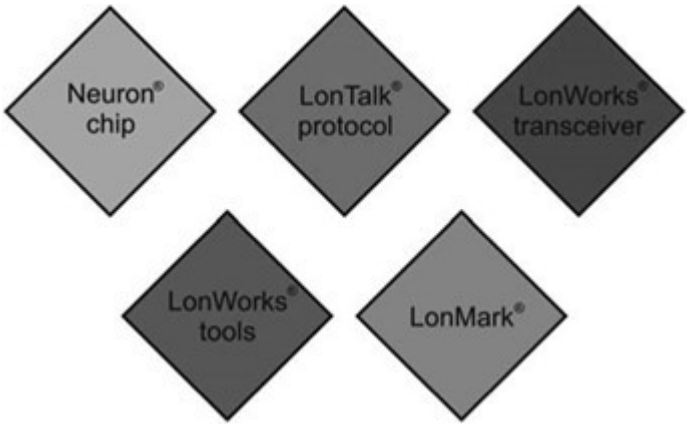

Fig. 83: elements of the LonWorks technology

The Neuron Chip provides the LON device with its intelligence. It contains the LONTALK protocol. Its memory stores all programs that provide the functionality and run the desired applications. Neuron Chips have three internal . Each of them carries out different functions (Fig. 84).

- CPU 1 is responsible for physically accessing the transmission medium. A network interface provides access to the transceiver. This represents layers one (physical layer) and two (data link layer) of the ISO/OSI model.
- CPU 2 is responsible for transmitting network variables and represents layers three to six of the ISO/OSI model.
- CPU 3 processes application programs, but does not access the network; this is done by the other two CPUs. The CPUs exchange data with each other by accessing the shared random access memory (RAM).

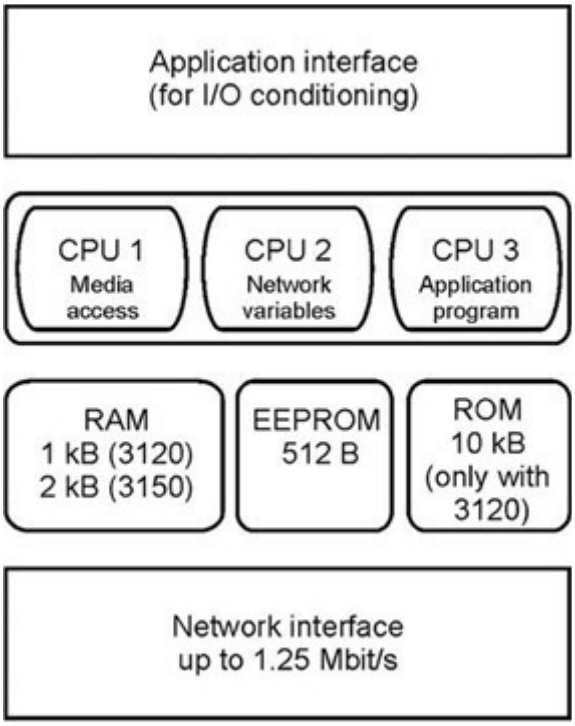

Fig. 84: internal components of neuron chips

The LONTALK protocol defines how Neuron Chips are programmed for different applications and how they communicate with each other as nodes in a network. This requires a standard language, or communication protocol. The LONTALK protocol is an integral part of the Neuron Chip and is embedded directly in the chip as firmware. This ensures that all LON nodes connected with each other on the same network are compatible.

Each network device has a transceiver - short for transmitter and receiver - . The transceiver provides a physical communication interface between a LONWORKS device and a LONWORKS network. There are specific transceivers for each medium: twisted pair, power line, radio frequency and fiber-optics. The most commonly used medium is twisted pair.

Echelon and other manufacturers offer various programming and integration tools for LON technology. Firstly, Echelon provides development tools, LONBUILDER and NODEBUILDER, which allow developers to program their own applications into the Neuron Chips. Secondly, there are a variety of network tools available, such as LONMAKER from Echelon, for customizing LON devices and integrating them into a fully functional network.

The LONMARK Interoperability Association is responsible for defining a device's basic functionality and minimum requirements as well as the standard network variable types (SNVT).

A device that has been certified by the LONMARK Interoperability Association is guaranteed to be interoperable with other LONMARK-certified devices from other manufacturers.

Transceivers and transmission medium

FTT-10A Free Topology Transceivers: LONWORKS installations, particularly those in individual rooms, can be freely configured to fit a particular room or building. Free topology, as it is known, means that you can implement star, loop, linear and mesh topological structures as well as mixed configurations. Due to this high level of flexibility, however, a free topological network is limited to a range of 500 m. For a larger network of up to 2700 m, you must implement a bus (linear) topological structure. Twisted-pair cable is used, because it is relatively inexpensive.

A FTT-10A transceiver contains a transformer to galvanically isolate the LON device from the network. This also means that components can be connected to the bus cable regardless of the polarity. However, if the network contains ring structures, the polarity of the network line must be respected. The LON node receives its power separately from the 12/24 V (DC/AC) voltage (common in the world of automation) or the power line. The transmission rate of 78 kbit/s is also fast enough to transfer analog signals.

LPT-10 Link Power Transceivers: using the link power transceiver means that you do not need to install a separate power supply. The LON device takes its power directly from the bus cable. A DC voltage of 42 V is superimposed onto the AC voltage signal. The device's power adaptor is connected to the bus and supplies the device with the required operating voltage. The transceiver separates the bus signal and the operating voltage, providing the LON node with an electric current of up to 100 mA from the network. This is enough to power, for example, heating valve actuators, LEDs and relays. Free topology (FTT) and link power (LPT) transceivers can be used in the same network. The bus cable can be laid in a number of different ways. All topologies, except the ring architecture, are not sensitive to polarity. Like FTTs, LPTs support a free topological architecture limited to a range of 500 m. For a larger network of up to 2700 m, a bus topology must be used. LPTs also use twisted-pair cable with a transfer rate of 78 kbit/s.

Smart-Transceiver FT 5000: the FT 5000 smart transceiver integrates a Neuron chip in a free topology transceiver. It is compatible with both FTT and LPT transceivers. The combination of components allows the development of cheaper products and the user can save even more if he uses the LonMaker during installation in the LON network.

TPT/XF-78 and TPT/XF-1250 Twisted-Pair Transceivers: in addition to the transceivers mentioned in the previous sections, there are other types of transceivers that can be used with twisted-pair cable: the TPT/XF-78 and TPT/XF-1250 transceivers. These both have an in-built transformer that isolates them from the network, denoted by XF. The LON devices have separate power supplies. These transceivers can only be used in a bus topology network that has not

been expanded. The bus devices are connected to the bus via a short length of cable, or they are connected in a line and the signal passes from device to device. This allows them to communicate over long distances, but it does mean that these transceivers are not suitable for connecting LON devices in a room. The TPT/XF-1250 transceiver also has a very fast transmission rate of 1.25 Mbit/s, which means it is perfect for pathways that transfer a large amount of data, for example, pathways connecting high-performance DDCs to devices at the management level. The TPT/XF-1250 can also be used to connect various LON subnetworks over a router to form a loop or backbone network.
LON devices with twisted-pair transceivers (TPT) cannot be used with LON devices with free topology (FTT) or link power (LPT) transceivers, even though they use the same transmission medium.

PLT-22 Power Line Transceivers: power line transceivers (PLT) provide an alternative to FTTs and LPTs particularly when refitting existing buildings. For example, a new energy meter installed in an old house would be fitted with a PLT.
A PLT enables a device to transfer a signal over the existing power line. By sending the LON signal on the power line, you do not have to rip up floorboards and knock holes in walls to lay any additional bus cables.

The PLT-22 transceiver uses a frequency range from 125 to 140 kHz for transferring data. In the aforementioned transceivers, data is transferred over separate bus channels. With power line technology, however, other loads are connected to the power line as well as the LON devices. Signal noise can occur depending on the type of loads on the power line. For example, energy-saving lamps and traditional switch power adaptors can cause particular problems on the network. In addition, the electrical properties of the power line itself can cause signal attenuation. These factors mean that the maximum length of the network depends on the attenuation and the noise (interference). To reduce the amount of interference, the transmission rate is limited to 5 kbit/s.
The transceiver PLT-30 is another type of transceiver that works with the frequency reserved for European energy suppliers of 9–95 kHz. Especially electricity meters are often equipped with it to allow remote data requests.
The table below summarizes types of transceivers mentioned in this section.

Transceivers and network topologies

Medium	Transceiver	Transmission	Network	Network	Power supply
Twisted pair	FTT-10A	78 kbit/s	Free topology, bus	500, 2700 m	Separate
Twisted pair	LPT-10	78 kbit/s	Free topology, bus	500, 2700 m	Via the bus
Twisted pair	TPT/XF-78	78 kbit/s	Bus	1400 m	Separate
Twisted pair	TPT/ XF-1250	1.25 Mbit/s	Bus	130 m	Separate
Power line	PLT-22	5 kbit/s	Free topology	Depends on attenuation and interference	Via a specialized power adaptor

Physical Network Topologies

A LON network has a unique physical architecture. The smallest component in a network is a Neuron Chip, which represents one LON node. If a device such as a powerful DDC contains a number of Neuron Chips, then each of these in-built Chips represents one LON node. This section will show network topologies used to connect each device.

Bus network: LON nodes that have a direct relationship with each other should be directly connected to each other. The greatest distance can be achieved using a bus topology as shown in Fig. 85. To prevent the signal from being reflected back at the end of the cable, terminators (T) with a resistance value of R = 107 Ω are placed at both ends of the bus cable.

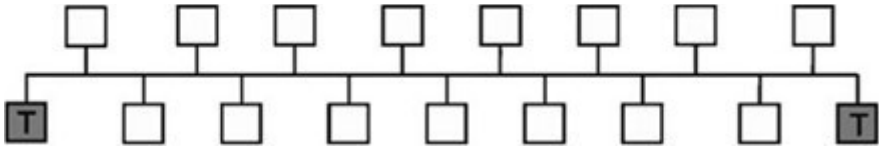

Fig. 85: LON nodes in bus topology with terminators

Star and ring networks: they can be implemented when using free topology transceivers. Both topologies are shown in fig. 86. A terminator with the value of R = 52.3 Ω is placed at the end of the network. A closed ring network is particularly suitable for the installation of LON devices in rooms. It allows you to refit components at a later date, without having to think about installation guidelines. What is important, however, is to observe the polarity of the bus channel. If you do not, then this could cause a short circuit, resulting in network failure.

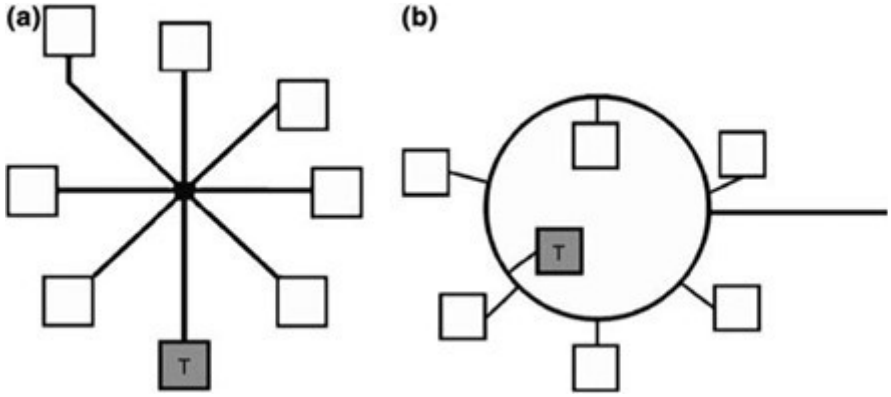

Fig. 86: physically connected LON nodes in a star network (a) and a loop topology (b)

Subnets: represents the smallest part of a LON network. A subnet can contain a maximum of 128 addressable LON nodes (Fig. 87). LON devices that operate directly with each other should be put in the same subnet. By doing this, you minimize the time it takes to execute a command. For example, light switches and the corresponding lamp actuators should always be in the same subnet.

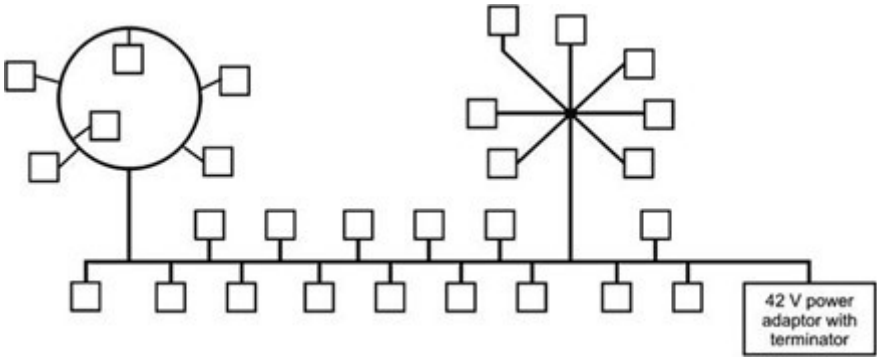

Fig. 87: a subnet in a free topology network

Repeaters and Routers: a repeater connects two segments of the same medium, but does not filter valid data frames. A maximum of three repeaters can be installed in a row; more can cause signal delays, which can lead to communication problems. Subnet with repeaters is shown in fig. 88. If you want to use different transmission media in a LON network, then you must connect these media using a router (Fig. 89). In LON terminology, the segments are known as channels. Routers can be used, for example to connect power line devices with FTT devices. You should note, however, that a router does not increase the number of nodes that can be addressed in a segment, it simply divides the various physical channels into different subnets. Another difference between routers and repeaters is that a router can also filter data frames. It uses a routing table to determine whether a data frame is addressed to a node in the same network segment. It only forwards the data frame if the address is in the next segment. This way a number of subnets can be combined into one large network. The router counts as LON node.

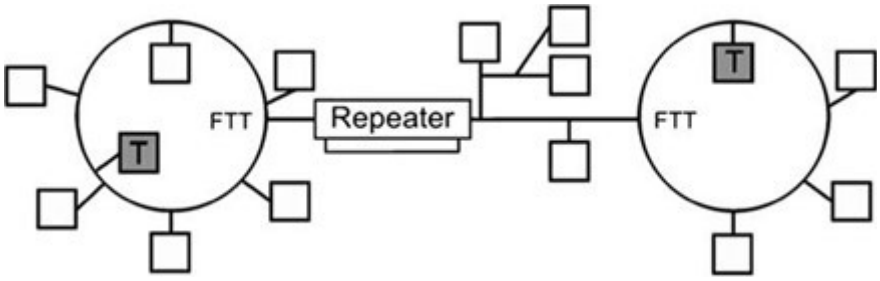

Fig. 88: a subnet with a repeater

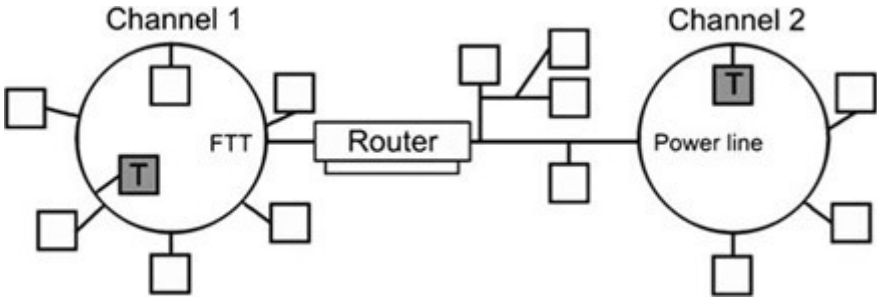

Fig. 89: a router connecting subnets and channels

Signal Coding

In the LONTALK protocol, bus nodes (devices) that have equal access rights to the transmission channel use the predictive p-persistent Carrier Sense Multiple Access (CSMA) protocol to communicate with each other (where p stays for probability). All the nodes first listen to the

transmission channel to see if a carrier (signal) is being transmitted by another node. Once the channel is idle, all the nodes must wait for a delay period to elapse. Once this delay has elapsed, each node then waits for a random delay period to elapse before transmitting (Fig 90, top). The length of the delay and the data frame varies depending on the type of transceiver. If no other LON node is accessing the network during a particular node's random delay, then this node starts transmitting. If two nodes have exactly the same random delay and want to start transmitting simultaneously, then both nodes sense this and stop transmitting. This can lead to considerable delays if there are a large number of nodes in the network. One way of getting round this problem is to grant priority access to the channel (Fig 90, bottom). Each node is assigned a set delay period according to its importance. The node no longer has to wait for the random delay, but can, if required, start transmitting during the priority window it has been assigned.

As mentioned in previous section, FTT-10 and LPT-10 transceivers are polarity insensitive and can therefore be connected to the physical network regardless of the polarity. This is because the physical signals are encoded using the differential Manchester code. The differential Manchester code creates a clock transition for each bit transmitted. The logical "0" is represented by an additional transition within the clocking period. This means that it does not matter whether a low or high signal is sent; if there is no additional transition, then it is interpreted as a logical "1" (Fig. 91). As a result, the number of transitions within a clocking period determines whether it is a "0" or a "1" bit. There is no dependency on the polarity of the bus channel. Another advantage of this method is that there is always a transition from high to low even when a series of logical "1 s" is being transmitted. This is particularly useful when synchronizing bus devices.

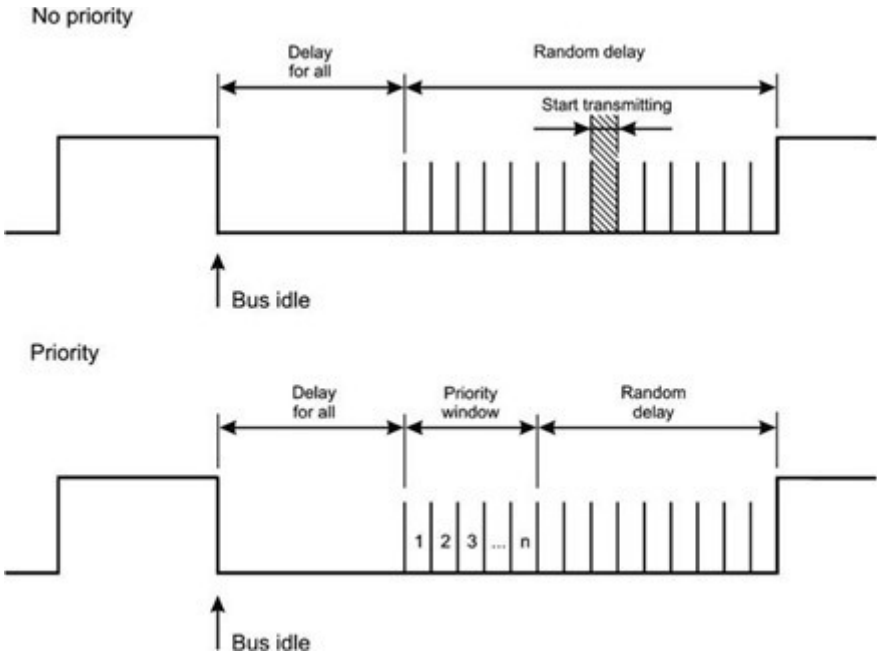

Fig. 90: predictive p-persistent CSMA used by LON nodes to access the network

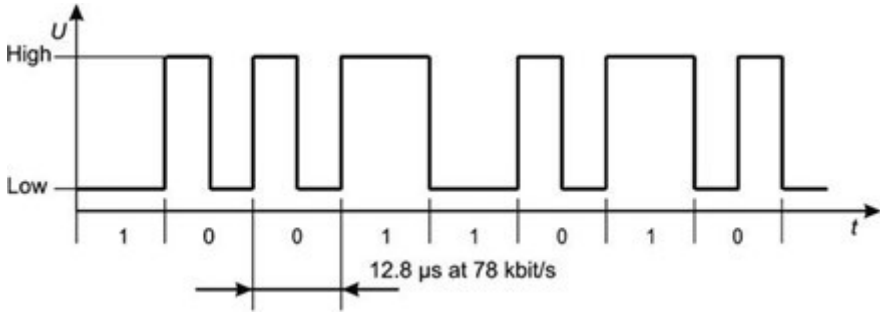

Fig. 91: the differential Manchester code

RESOURCES

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