Chapter 18
Building Automation Systems in the World of Internet of Things

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18.1 Introduction

The idea of a fully functional smart home has been a dream since the mid of the twentieth century. The first trials started in the 1960s with the use of domestic smart devices, but this has become a reality only during the last decades. Smart home, as a term, was also introduced in 1984 by the American Association of Housebuilders. Since then, things have dramatically changed with significant advances in the domain of intelligent building control. More specifically, houses, schools, and offices security can be drastically enhanced through electrical and electronic equipment while their energy footprint minimized with inner climate control which maximizes the comfort and safety of the occupant. This can be

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achieved, for example, by remote mobile control, automated lights, automated thermostat adjustment, scheduling appliances, mobile/email/text notifications, and remote video surveillance.

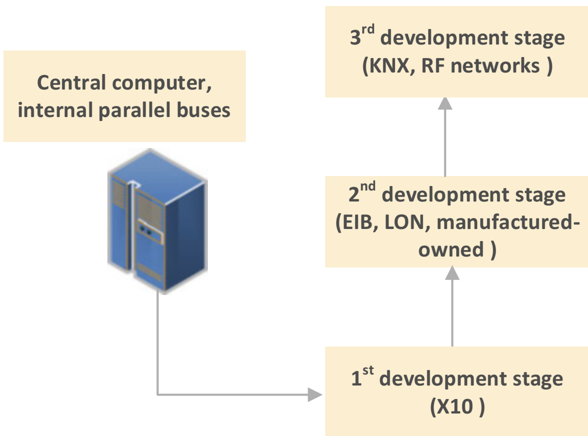
This chapter provides an overview of the latest technologies for smart home/building related technologies and introduces KNX, as an emerging standard for interconnecting KNX of Things and combining them with the world of Internet of Things (IoT). The rest of the chapter is organized as follows: Sects. 18.2, 18.3 and 18.4 provides an overview of the technology evolution of building automation systems, while Sect. 18.5 presents the major requirements of modern home/building automation. Sections 18.6 and 18.7 detail how building automation systems can be combined with IoT and KNX of Things, respectively. Section 18.8 outlines how KNX gateways can be used for developing intelligent home and building infrastructure, while Sect. 18.9 presents a real world implementation that combines KNX of Things with IoT prominent technologies. Finally, Sect. 18.10 concludes and presents the future work.

18.2 Evolution of Building Automation Systems

Most *Building Automation Systems* (*BAS*) consist of wired buses or wireless broadcast networks, which connect high-level controllers. Initially, bus systems were developed in the field of computers and protocols for BAS such as the X10 protocol which offered a limited number of instructions, low data rate while characterized by compatibility problems. The second stage of development with bus systems such as EIB, LON, and other proprietary systems with devices from different manufacturers aimed for better compatibility. Currently, in the third development stage, there is further market penetration for bus systems, increased degree of system integration and an increasing use of the radio frequency (RF) bus systems (Fig. 18.1).

In BAS, there is a wide range of technology platforms and protocols a user/designer/developer can select from. Each of them has pros and cons. Amongst them,

Fig. 18.1 Bus systems development stages



most popular are those offering *open protocols* and *support a large number of devices*, as well as those that offer *device interoperability*. Cost, energy consumption, and bandwidth are also essential parameters, as well as the programming language(s) and the maximum number of connected devices supported. The most popular home automation wired and wireless platforms are detailed in the following sections.

18.3 Wired Protocols

18.3.1 BACnet

BACnet (http://www.bacnet.org/Tutorial/HMN-Overview/sld039.htm), [9, 11] is one of the most popular communication protocols with many implementations in building automation systems (HVAC—Heating, Ventilating and Air-conditioning Control, Lighting Control, Security, Smart elevators) and control networks. The BACnet protocol was initially developed by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) project committee. Today, BACnet is covered by two standards: international ISO 16484–6 and ANSI/ASHRAE STANDARD 135 (http://www.bacnet.org/Overview/). BACnet supports many different communication protocols (ARCNET, Ethernet, BACnet/IP, Point-To-Point over RS-232, Master–slave/Token-Passing over RS-485, Lon Talk, or KNX-IP). The most common serial version is called BACnet MS/TP (master–slave/token-passing) which is a twisted pair wiring and is intended for devices with lower requirements in terms of speed. It runs at speeds of up to 1 Mbps while the dominant Ethernet version is BACnet/IP and supports several types of media UTP, fiber, or even wireless with data rate of up to 10 Gbps. BACnet communication is based on “objects” (analog input/output/value, binary input/output/value, loop, calendar, program . . .). An object is effectively a collection of information related to a particular function that can be uniquely identified and accessed over a network in a standardized way.

One of the disadvantages of the BACnet is that there is no common configuration tool (in contrast to KNX). Therefore, manufacturers have to develop their own new (and typically non open-source) tools for their devices. Secondly, the device interoperability is limited, since some BACnet products are not fully compliant to each other.

18.3.2 LON

LonWorks [1, 2, 9, 11] (http://www.rtaautomation.com/technologies/lonworks/, http://www.lonmark.org/technical_resources/standards) was created by Echelon Corporation in 1988. LonWorks is a Building Automation Platform based on LonTalk communication protocol. The LonWorks platform is a distributed control system that enables peer-to-peer as well as master–slave communication among intelligent devices. The LonWorks platform supports a wide range of different physical media including free topology twisted pair transceiver (FFT-10A) [3], power line, radio frequency, infrared, fiber optic, and coaxial cable.

One of the main features of Lon is IP-tunneling based on the ISO/IEC 14908–4 (ANSI/CEA-852) standard (http://www.lonmark.org/technical_resources/standards). There is a special transceiver for every physical layer which is transforming its specific signals to standardized input signals for the connected Neuron chip. The LonWorks platform can manage almost every task in BAS from room temperature control to security and access control systems.

LonTalk, similarly to BACnet or KNX, supports several international and national standards which are shown in Table 18.1. All LonWorks-based devices comprise of a Neuron chip which contains a complete system. The most important part of the neuron chip is the 48-bit serial number, which is unique for every device. This is important for the identification in an installation, while the main disadvantage of all Lon talk devices is their dependency on the neuron chip itself. The Neurons contain the entire LonTalk protocol stack and are comprised of three 8-bit CPUs (two for the protocol and one for the application). There are two basic types of Neuron chips, the 3120 and the 3150 which are functionally equivalent except from memory configuration and packaging.

In order to allow system interoperability, the standardization of the variables used to describe physical things in LonWorks is of paramount importance. This list of standards is maintained by LonMark International and each standard is known as Standard Network Variable Types (SNVTs). One drawback of Lon is the fact that the devices made by different manufacturers have different development software. Most of the tools are based on the additional programs of the unified Echelon database platform (LNS) (plug-in) which enables the parameterization via Windows dialog boxes.

18.3.3 KNX

KNX [4–9, 11] is an open, worldwide standard used for more than 25 years. The KNX building automation system was developed at the beginning of 1990s by the European Installation Bus (EIB). In 1999, EIB Association, Batibus Club International (BCI, France), and the European Home Systems Association (EHSA, Netherlands) have been merged. The result of this merging is a new association called “KNX Association.”The supported standards for KNX are shown in Table 18.1. The KNX association nowadays consists of more than:

- 400 manufacturers in 37 countries
- 48200 KNX Partners in 139 countries
- 360 KNX Training Centers in 59 countries
- 120 Scientific Partners in 30 countries comprised of Universities all over the World

Table 18.1 Features of wired protocols employed in BAS

Standard	KNX	LonWorks	BACnet
Number of bus devices	58384 addressable devices, whereby many devices have realised several input/output points	32385 devices per domain. Several input/output points are often implemented in a device	127 MS/TP masters
Expansion	700 meters per galvanic unit, possible to extend complete system by many kilometers		1200m MS/TP Twisted Pair cable
Transmission medium	Twisted twin core cable, Powerline, Radio, IP network individual sections of Optical fibre	Various types with twisted twin core cable, Powerline, Radio, Infrared, Fibre glass	BACnet IP, BACnet LonTalk, or BACnet MS/TP
Topology	With twisted twin core cable: tree structure	Very varied depending on the selected transmission type	Line or star topology (Standard Ethernet topology)
Applications	Building Management Automation, Lighting, blind control, heating, ventilation access control, media, security, monitoring, visualisation and load management	Lighting, blind control, heating, ventilation access control, monitoring, visualisation and load management	Building Managment Automation, HVAC plants, fire control panels, smart elevators, intrusion detection and access control systems
Maximum Data Rate	9,6 kbit/s	78 kbit/s	10/100 Mbit/s full duplex
Standards	International Standard (ISO/IEC14543-3) European Standard (CENELEC EN50090 and CEN EN 13321-1 and 13321-2) Chinese Standard (GB/T 20965) ANSI/ASHRAE Standard (ANSI/ASHRAE 135)	ANSI/CEA-709.1-B EN 14908-1:2005 IEEE 1473-L GB/Z 20177.1-2006	international ISO 16484-6 ANSI/ASHRAE STANDARD 135

The technology used in modern KNX devices is compatible with that of the old EIB system, so all devices bearing either the KNX or the EIB logo are mutually compatible. The KNX certification process ensures seamless cooperation and communication amongst different products of different manufacturers used in different applications. This ensures a high degree of flexibility concerning the extension and the modification of installations and wide scale deployments.

Similarly, to other typical complex standardized protocols, KNX uses more than one physical layers:

- KNX TP (separate bus cable)
- KNX PL (existing mains network)
- KNX RF (via radio signals)
- KNX IP (via Ethernet or Wi-Fi)

The KNX installation can be configured with a manufacturer-independent tool called Engineering Tool Software (ETS) [4]. Thus, the KNX system avoids typical problems of other standardized systems (e.g., BACnet, LonWorks) where each manufacturer has a special configuration tool, while it is often not possible to use one manufacturer's tool for devices (supporting the same protocol) made by another vendor. The ETS tool is managed by the KNX association and the manufacturers only have to add a plug-in to it.

In contrast to other protocols, KNX is independent of any hardware or software technology meaning that it can be realized on any microprocessor platform.

18.4 Wireless Protocols

18.4.1 Z-Wave

Z-Wave (http://z-wavealliance.org/) uses ITU-T G.9959 PHY/MAC with protocol stack from Sigma Designs. The international standard is maintained by Z-Wave Alliance. Z-Wave uses low power sub 1 GHz RF and works within a mesh topology. Z-Wave is one of the most popular wireless protocols for home automation. It transmits on 868.42 MHz (Europe) frequency band, while it is not affected by the interference generated by other household wireless products that usually work on 2.4 GHz. A significant advantage of Z-Wave is its interoperability; all Z-Wave devices talk to each other, regardless of their type, version, or brand, while Z-Wave devices are backward and forward interoperable. Z-Wave provides access to a wide range of devices with low power consumption. Z-Wave's mesh network makes all devices double as repeaters, which means that each Z-Wave device will pass the signal along to another until the final destination is reached.

18.4.2 ZIGBEE

ZigBee PRO (http://www.zigbee.org/) [11] offers full wireless mesh, low power networking capable of supporting more than 64,000 devices on a single network. It provides standardized networking designed to connect an extended range of devices from different manufacturers into a single control network, transcending interoperability issues with older versions. The latest version of ZigBee Home Automation standard, which is fully interoperable with the previous versions, adds several important new features that improve the battery lifetime for security sensors (with sensor lifetime over 7 years), standardize device pairing and simplify installation and maintenance. These features have significant impact on operational and equipment costs for the service providers, and on quality of service for the consumers. The Green Power feature of ZigBee PRO allows battery-less devices to securely join ZigBee PRO networks. It is the eco-friendliest way to power ZigBee products such as sensors, switches, dimmers, and many other devices.

18.4.3 Bluetooth Low Energy

Bluetooth (https://www.bluetooth.com/what-is-bluetooth-technology/bluetooth) is contained in many devices. It has higher data bandwidth than ZigBee and Z-wave. In Bluetooth 4 version (Bluetooth Low Energy or BLE) there is a significant decrease in power consumption. The latest version of the protocol, Bluetooth 4.2, makes Bluetooth a promising wireless technology for the IoT.

It is one of the most reliable and secure wireless standards. BLE Secure Connection includes Federal Information Processing Standards (FIPS) (https://en.wikipedia.org/wiki/Federal_Information_Processing_Standards) approved encryption, granting the ability to encrypt connections between devices under P-256 elliptic curve public-key cryptography. According to the ABI Research (https://www.abiresearch.com/) the market share for smart home applications, such as lighting, security, and energy management, based on Bluetooth will increase at a faster rate than any wireless technology over the next 5 years.

Bluetooth 4.2 uses the Internet Protocol Support Profile (IPSP) to connect Bluetooth Smart sensors to the Internet in order to send and receive transmissions through gateways via IPv6 (https://el.wikipedia.org/wiki/IPv6) and 6LoWPAN (https://en.wikipedia.org/wiki/6LoWPAN, http://www.ti.com/lit/wp/swry013/swry013.pdf).

The basic topology used within a Bluetooth ecosystem is the *piconet*, in which a master device can be interconnected with up to seven slaves. When there are more than two piconets interconnected to each other, the topology is referred to as *scatternet* (Fig. 18.3). A critical advantage compared to any competitive technology stems from the fact that BLE capitalizes on the wide acceptance and wide spread of previous versions of Bluetooth protocol. Therefore, even nowadays BLE interfaces are integrated in essentially any mobile phone, tablet, wearable device, etc., offering a huge precedence in dominating relative markets.

18.4.4 EnOcean

EnOcean (https://www.enocean.com/en/) technology is used primarily in building automation systems. The EnOcean standard is based on the international wireless standard ISO/IEC 14543-3-1X, which is optimized for ultra-low power wireless applications and energy harvesting. EnOcean energy harvesting wireless sensor solution is able to generate a signal of astonishing range from an extremely small amount of energy. Consuming just 50 μW a standard EnOcean energy harvesting wireless module can easily transmit a signal 30 m away (in-doors). The technology behind this is based on the signal duration since the entire process is started, executed, and completed in no more than a thousandth of a second. The latest generation of EnOcean energy harvesting wireless sensors requires standby currents of only 100 nA or less via gateways. There are also products which are self-powered (without battery) such as switches and sensors. EnOcean wireless solutions communicate with all major wired bus systems such as KNX, LON, DALI, BACnet, or TCP/IP.

18.4.5 Wi-Fi

Wi-Fi (http://www.wi-fi.org/) is supported by many applications and devices. The Wi-Fi Alliance owns and controls the "Wi-Fi Certified" which certifies all 802.11-based products for interoperability. It offers significantly higher data rates than any other wireless standard but its high power consumption comprises a notorious problem for the battery life in mobile devices. The Wi-Fi Alliance introduced Wi-Fi HaLow (http://www.wi-fi.org/) in January 2016 as an extension of the upcoming 802.11ah standard which is intended to be competitive with low power Bluetooth, but with a wider coverage range. The new wireless protocol operates on the 900 MHz band but retaining support for existing 2.5 and 5 GHz access points (http://www.wi-fi.org/).

18.4.6 THREAD

Thread (https://www.threadgroup.org/) is a new open wireless protocol for home automation, which was founded in July 2014 by vendors including Google's Nest Labs, Samsung Electronics, ARM Holdings, Silicon Labs, and other key players. Thread is based on the 802.15.4 radio standard. Contrary to the Wi-Fi paradigm, it is an IPv6-based mesh network in which product developers and consumers can easily and securely connect more than 250 devices into a low power, wireless network that also includes direct Internet, and cloud access for every device (Table 18.2).

18.5 Requirements for Building Automation System

When it comes to making a decision on choosing the appropriate BAS for a house or a building, there is a significant number of parameters that should be considered. The major requirements mainly needed are outlined in the sequel:

- *Basic BAS operation support*. Tasks such as scheduling occupancy, adjusting setpoints, troubleshooting complaints, responding to alarms, or checking of the system should be as simple and as intuitive as possible. It is essential to accomplish them in a fast and easy way and from any available terminal or remote device.
- *Low energy consumption*. The current demands must be constantly, accurately measured and analyzed, in order to have an effective and environment-friendly use of energy. BAS must provide facilities and services that will allow both monitoring and decision making in an efficient way.

Table 18.2 Features of wireless protocols employed in BAS

Standard	Z-WAVE	ZigBee	enocean	Bluetooth	WiFi	THREAD
Network Topology	Mesh	Star, Tree, Mesh	Mesh	Star/Point-toPoint	Star, Mesh	Star, Mesh
Power Usage	Low	Low	Low	Low		Low
PHY/MAC Standard	ITU-T G.9959	IEEE 802.15.4	IEEE 802.15.4	IEEE 802.15.1	IEEE 802.11	IEEE 802.15.4
ISM Radio bands	868.42 MHz (Europe) 908.42 MHz (United States)	2408 to 2480 MHz	868 MHz (Europe) 902 MHz(United States)	2.4 to 2.485 GHz	2.4 GHz	2.4 GHz
Number of bus devices	up to 232	up to 64000		7 devices in one piconet region		up to 250
RF range (indoor - line of sight)	30 - 100m	70 - 400m	30 - 300m	30 - 100m	200m	30m
Maximum Data Rate	9,6 - 100 kbit/s	20 - 250 kbit/s	125 kbit/s	1 - 24 Mbit/s	250 Mbit/s	250 kbit/s
Manufacturers	up to 330	up to 76	up to 100			
Applications	Home Automation	Home Automation, Building Management Automation	Home Automation, Building Management Automation			Home Automation
Power Efficiency	√	√	√	√	x	√
Certified products	up to 1400	up to 939	up to 1200		up to 25000	up to 30

- *Assurance of high quality indoor living*. Comfort management is one of the major requirements that must also be taken into account. Depending on the type of the inhabitant, it can range from simple environment monitoring to environment adjustment according to the need of people having chronic diseases, e.g., people having asthma.

In order to support the aforementioned requirements, there are several features that need to be supported and must be identified beforehand, since there is a wide variety of technology platforms or protocols on which a BAS can be build on. It is also important for the system integrator to be informed about the type of the building, i.e., whether it is a commercial or a residential one or any other type of different use. Furthermore, the region where the building is located, as well as the characteristics of the people who might be living or working there, should be taken into consideration.

As far as building automation is concerned, several of the protocols already described can cover one or more control levels. There is a three-level hierarchical model for automation and control systems [7], upon which building automation protocols can be employed. The first one is the *field level* which contains the connected sensors and actuators. The second one is the *automation level,* which includes all the applications that can be automated in a building. The last is the *management level* where control, operation, and monitoring take place. Figure 18.2 shows the three-level hierarchical model and indicates the level in which each standard can be used.

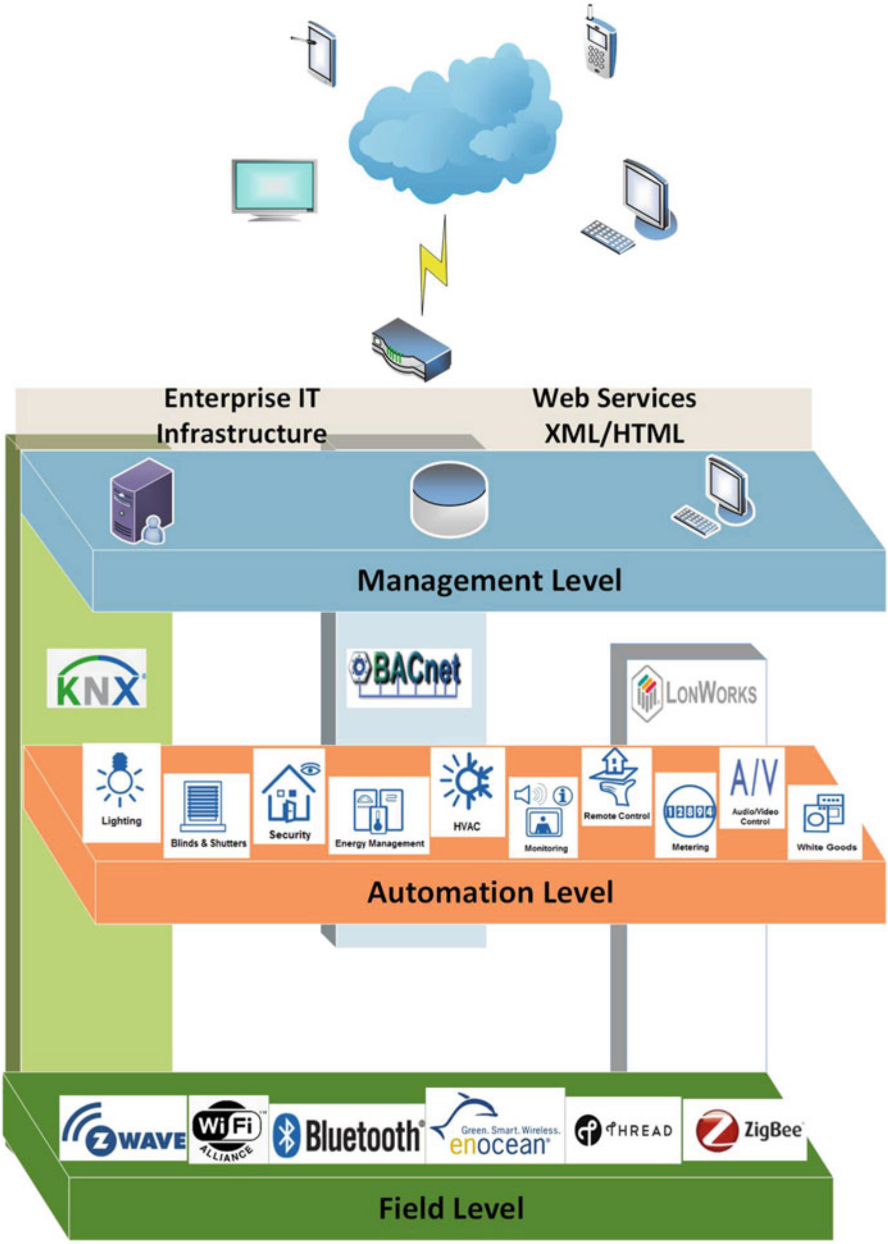


Fig. 18.2 Three-level hierarchical model of automation and control system

18.6 Building Automation Systems and "Internet of Things"

Nowadays, there are about 25 billion connected devices [10] on the Internet and it is estimated that by 2020 that number will be up to 50 billion. In a BAS, sub-networks employing different communication protocols have the ability to connect to the Internet either directly or through gateways. The same applies when we have to connect different sub-networks with each other in a single installation. The goal, in this case, is to use a protocol suite, which covers the majority of the installed devices and their corresponding applications within the specific context. Furthermore, a protocol suite must cover all or most of the communication media (twisted pair, power line, and radio frequency) and internet protocol (IP)-based networking. The interconnection of all BAS is realized through a main router with the appropriate IP gateway of each communication protocol as shown in Fig. 18.3.

In a *new building*, the use of a *wired decentralization protocol* like a bus system is strongly recommended. This approach offers critical advantages such as reliability, connectivity, and facilities for future improvements. For instance, if one unit of a bus system fails, the remaining system continues to operate without any problem in contrast to a centralized one. An Ethernet cable CAT 6 should also be placed near TVs, computers, IP cameras, security systems, and anywhere else where it may be useful to connect via a high-speed interface appropriate for media applications and

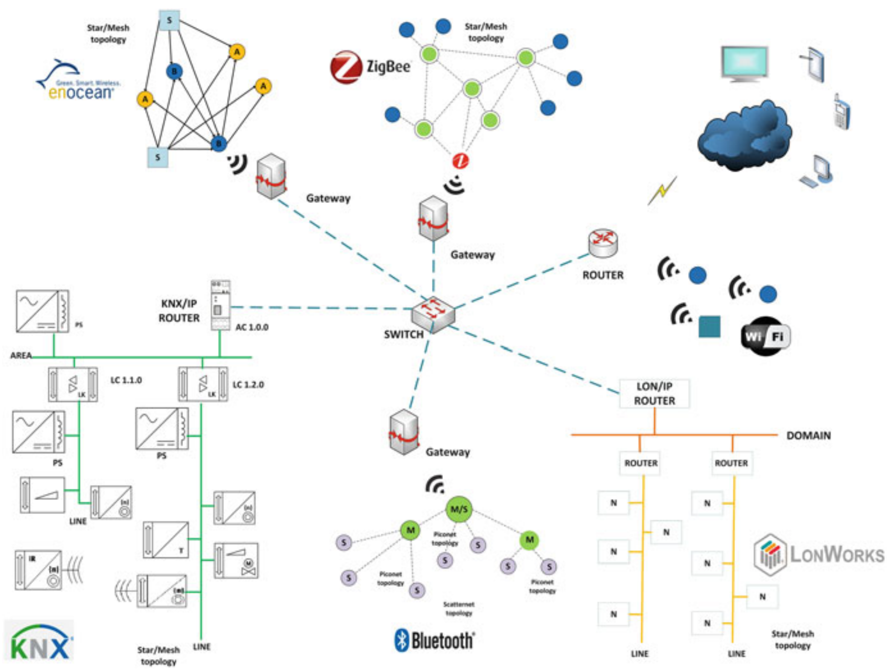


Fig. 18.3 A typical topology allowing BAS to participate in Internet of Things

communication to application servers. This makes possible for remote access and control of the installation covering any future needs.

On the other hand, in cases such as a *reconstruction* or a *renovation*, there are different approaches depending on the variety of uses. In such circumstances, the use of *wireless home automation protocols* offers significant practical advantages. However, it would be essential to have a *combination of wireless and wired communication* media with the same or different protocols.

During the last years, wireless protocols have been improved and they are leading the IoT paradigm. They have an extended use and one of the most pronounced objectives is energy efficiency. Ultra-low power devices with current demands as low as few μA offer a gain of 10–15 years battery life with a small coin cell battery. They can be even more efficient by incorporating intelligence enabling to turn into sleep mode power hungry components (e.g., radio interface, processing unit, and mechanical parts) yielding even less power consumption. Furthermore, each device tends to be more and more complex since they are composed of multiple sensors. Finally, there is no need to have a wiring infrastructure running from a central controller to switches and keypads throughout the house in order to enjoy a more connected home.

The most recent trend is towards a direct IP addressability of every single node of a wireless network, as in the case of THREAD (described in Sect. 18.4.6) for example, which allows a more immediate communication between the end nodes. Apart from THREAD, IPv6 communications are now also used in newer Bluetooth versions as well as Wi-Fi. IPv6 is able to offer a complete cover across all different networks in a home/building automation. However, native IPv6 implementations often prove to be too complex and resource demanding for typical hardware encountered in IoT platforms coming from the words of embedded systems and WSNs characterized by extremely limited resources in all aspects. A prominent and widely tested solution is the 6LoWPAN (https://en.wikipedia.org/wiki/6LoWPAN, http://www.ti.com/lit/wp/swry013/swry013.pdf), effectively comprising an implementation for IPv6 specifically targeting platform with scares resource availability (e.g., IEEE 802.15.4, ZigBEE, etc.) allowing each sensor to have its own IP address and in this way realize the ultimate objective of IoT approach.

18.7 Building Automation Systems and the "KNX of Things"

IoT comprises by devices of any standard that is already or will be able to offer Internet connectivity in the near future. There is an interconnection between several decentralized intelligent components, which communicate directly and autonomously via the Internet. KNX with all these applications/devices and interfaces to other systems is already used similarly to the "Internet of Things" and it provides the possibility of central controlling and monitoring through the KNX/IP gateway as shown in Fig. 18.4.

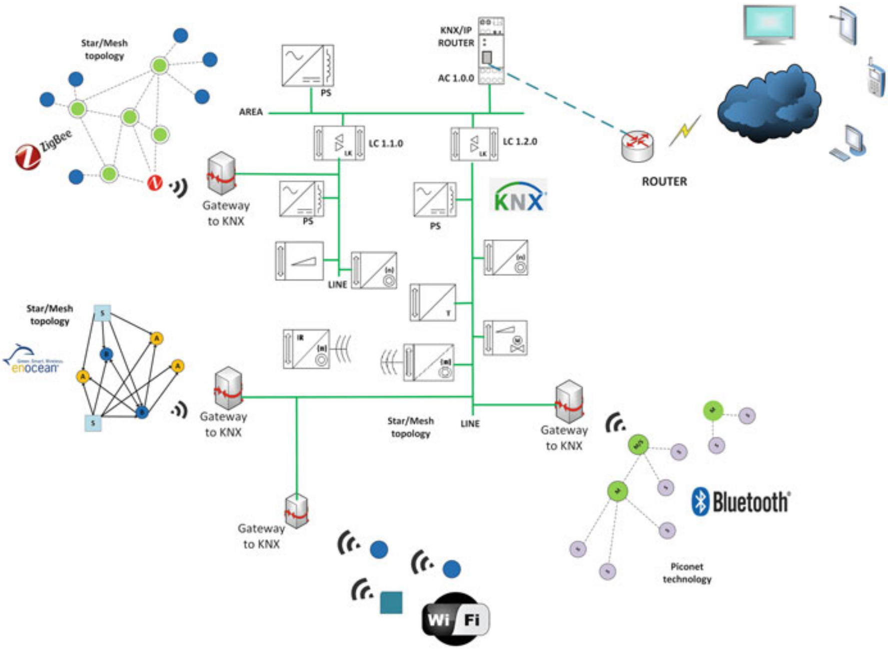


Fig. 18.4 Topology for KNX of Things

Many companies provide solutions for home/building control such as Google's nest (https://nest.com/) and Apple's Homekit (http://www.apple.com/ios/homekit/), through applications which unify different standards under a single interface. However, this trend has many drawbacks such as increased complexity and sometimes reliability problems. Such solutions require a central server or controller for the communication of different protocols. This is the reason why systems should be chosen to enable a more sophisticated level of customization, including the ability to work with a broader field of products and systems. For instance, typically there is no strict need to access every single data object in a home/building.

KNX is one of the most complete communication protocols designed as a decentralized bus system supporting all kinds of physical layer alternatives such as twisted pair, radio frequency, power line, IP/Ethernet, and Wi-Fi. Bus devices can be either sensors or actuators required for controlling the building management equipment. KNX can be used for all application areas in home and building control and for a variety of functions, ranging from lighting and shutter control to security, heating, ventilation, air-conditioning, monitoring, water control, energy management, as well as household appliances, and audio systems (Fig. 18.5). Another advantage of KNX is that it is easily adapted for use in different kind of buildings both new and existing ones.

The KNX standard has many different configuration modes which can be used according to the target market and typical applications as shown in Fig. 18.6. One

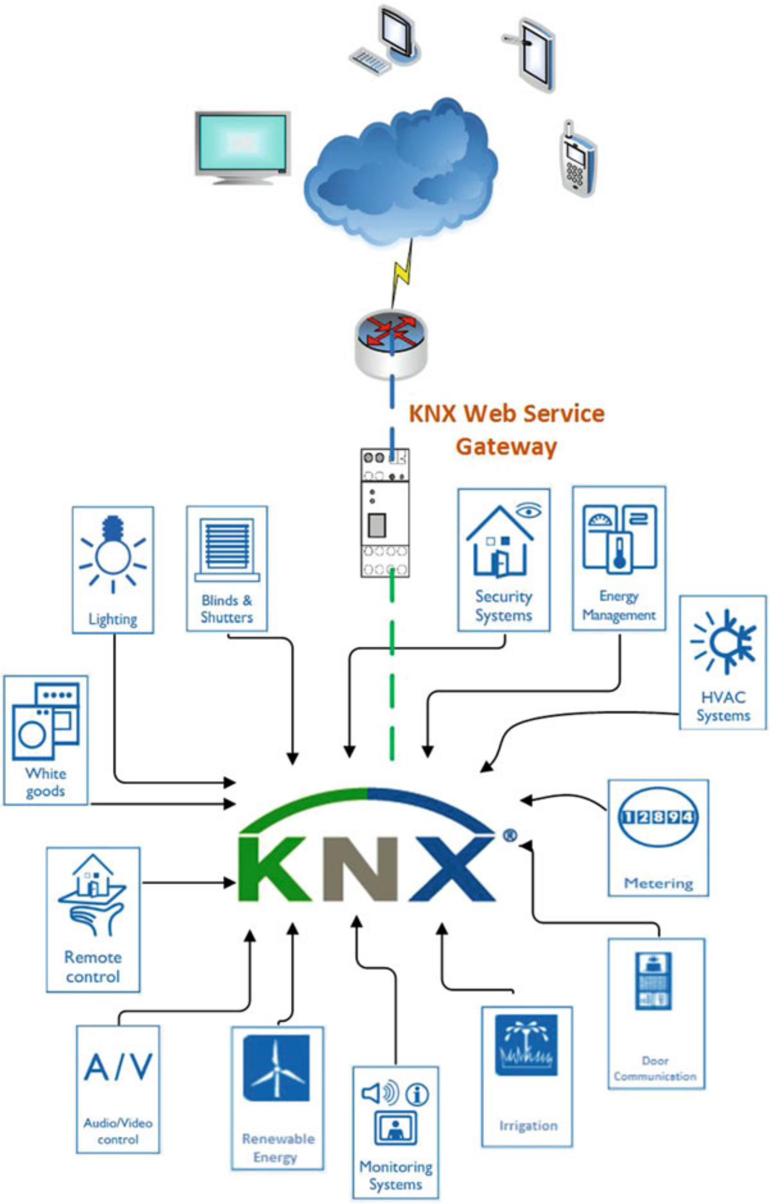


Fig. 18.5 KNX Web Services

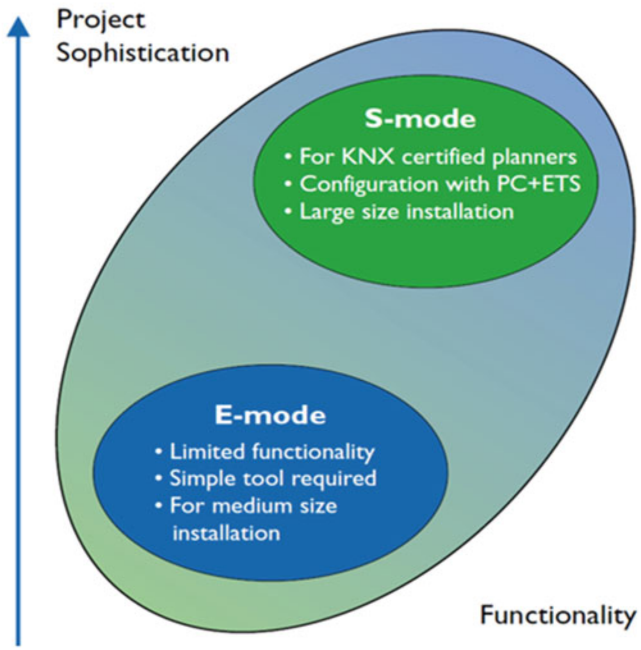


Fig. 18.6 KNX operation modes "Konnex Association"

of its tools is ETS Professional for the "S-Mode" components which are the same for all the KNX products, regardless the manufacturer.

18.8 KNX Web Service Gateway

The communication of KNX applications via an IP-based network is available for more than 10 years. The IP router uses the KNXnet/IP standard defined by KNX Association and ensuring two functionalities. The first is *KNX/IP Routing* which allows the interconnection of any remote KNX installation, especially for extended installations where considerably higher bandwidth may be required in the backbone. Here, the high bandwidth of a LAN network offers an optimal solution. While with KNX twisted pair a maximum of only 25–50 telegrams (data packets) can be transmitted per second, according to their length, transmission via LAN exceeds 10,000 telegrams at 10 Mb/s. To process this traffic without loss or excessive delays, a high computational power is required in addition to an adequate telegram buffer from IP to KNX TP. An IP router is used as line or backbone couplers in a KNX installation. Figure 18.7 depicts an example of a KNX/IP Routing.

The second is *KNX/IP Tunneling* which enables the IP-based access of a terminal device to a KNX installation. KNX tunneling is the technique used by web clients,

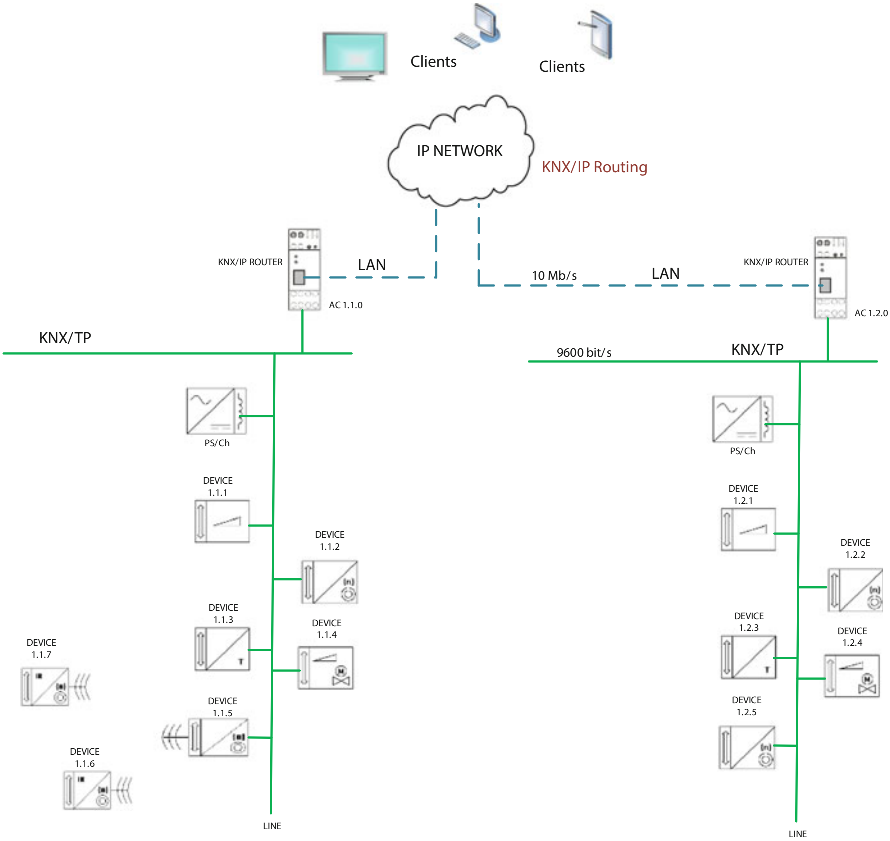


Fig. 18.7 KNX/IP Routing

computers, and smart phones to communicate with KNX devices in order to provide services to the end user. A typical example of KNX/IP Tunneling is shown in Fig. 18.8.

Using of a simple IP/KNX Router it is not easy to have access over the Internet to a KNX installation without support from an Information Technology (IT) expert. However, typically building automation is an unknown field for IT experts. A solution for this sector would be a translator connecting both worlds without the need for each party to have insight of other side. KNX Association has recognized this trend and developed the corresponding solution “KNX Web Services” (KNX WS) [8], which is realized using web services like oBIX, OPC UA, and BACnet-WS. Web services are self-contained modular software components that can be described, published, and activated via the web. Usually, they are employed by applications and not by persons. Thus, a simple and multi-faceted communication between web services and systems of building automation is possible.

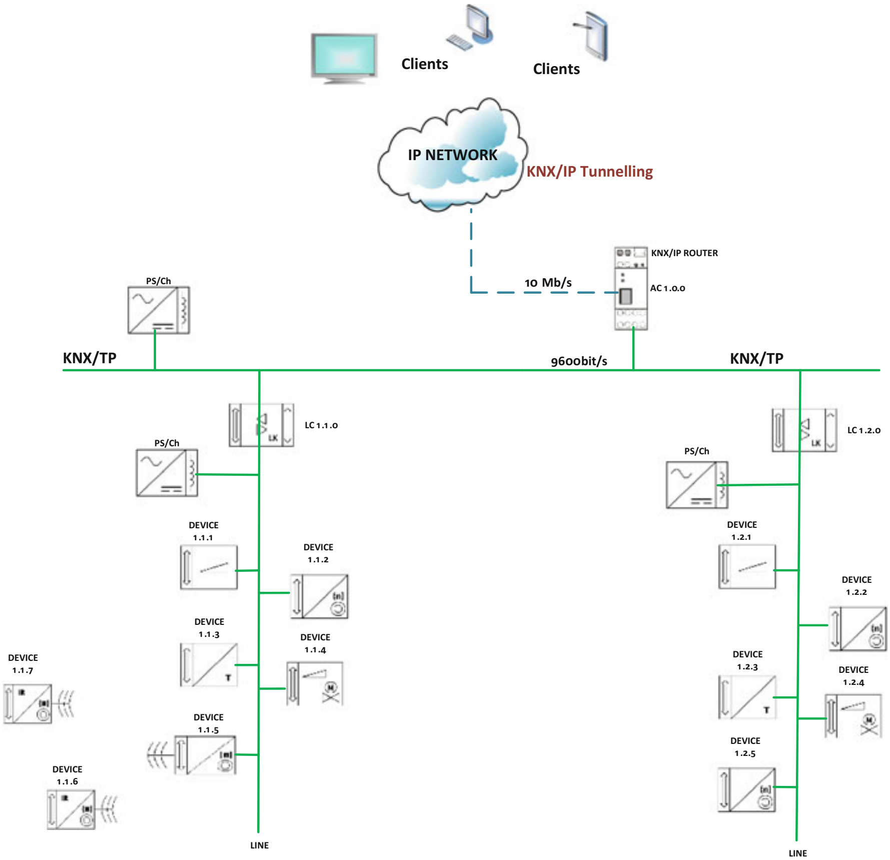


Fig. 18.8 KNX/IP Tunneling

18.9 KNX of Things in Practice: Design and Implementation of an Ambient Assisted Living Residence

Using the components described in the previous sections, an Ambient Assisted Living Environment that combines the world of the IoT with the world of KNX of Things has been designed and developed. It is called Ambient Assisted Living House (AAL House) [13] and it is a fully functional 60 m^2 residence for *applying*, *experimenting*, and *evaluating* state-of-the-art ambient assisted living technologies. One of the main design goals of AAL House is to provide an ambient environment with services for elders and people with chronic diseases.

The architecture of the AAL House is designed in accordance with the three-level hierarchical model for automation and control systems already described in Sect. 18.5, where the wireless sensors (ZigBee, BLE, and EnOcean) are located in the *field level*. Their task is to record human physiologic parameters, such as

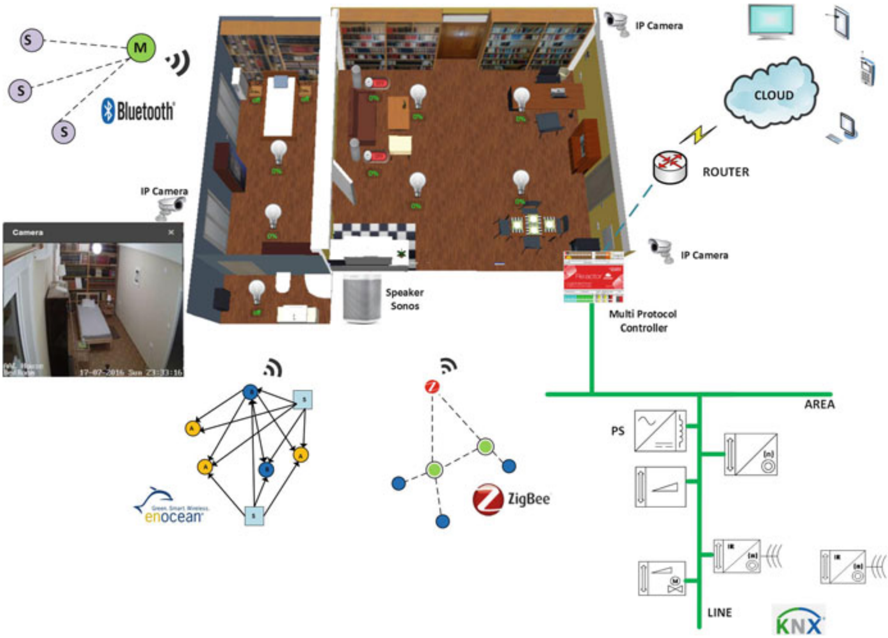


Fig. 18.9 Internet/KNX of Things infrastructure of AAL House

temperature and heart rate, as well as room air quality (CO_2) and humidity. A wired protocol is also available in the field level which is supported by KNX and it is responsible for the functionality of home automation. It basically triggers the appropriate functions according to the signals received from the sensors.

The programming of the automation functions is located at the *automation level*. Last but not least is the *management level*, where the monitoring and control of AAL House is realized. This is where a controller, LogicMachine Re:Actor V3 (http://openrb.com/logicmachine-reactor-v3/), is located, which contains all the interfaces for the heterogeneous communication protocols of the AAL House and is also in charge of the interaction between the different protocols. The controller is also connected to the Internet and it offers the possibility of remote control and visualization of the AAL House. An overview of the AAL House infrastructure is presented in Fig. 18.9.

As already mentioned above, special groups of population can benefit from living in a smart home environment. Currently, there are protocols and sensors (mainly wireless coming from the CyberPhysical and Wireless Sensor Network domains) which are used for monitoring individuals through special parameters of their body. These could be adopted and integrated into the KNX installation in such a way that the greatest comfort and safety is achieved. So far, KNX has the ability to regulate heating and air-conditioning systems, so as to reach the desired room temperature

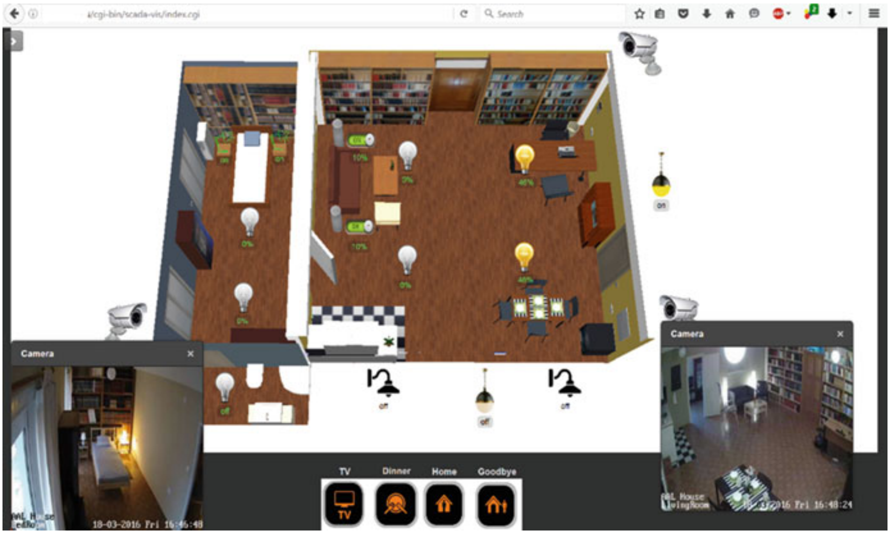


Fig. 18.10 AAL House project

with energy efficiency. But this could also be done automatically, according to the special needs of a person which are determined by biological parameters using Z-Wave, ZigBee, and BLE sensors.

Remote control of room functions or making phone calls through the room's sound system and voice demand are also typical examples how inhabitants with kinetic disorders can benefit from the infrastructure and services offered by AAL House. In addition, alert generation is also supported in case of a fall is identified or in cases of rapid change in the body's physiologic parameters (e.g., in body temperature or in electrocardiography parameters).

AAL House smart home infrastructure allows also the monitoring of a wide range of parameters related to environment, such as humidity and CO_2 monitoring. Especially for the case of emergency, like a fire, AAL House is equipped with devices and services that allow automatic door unlock, lighting of safety path, and automatic call of fire department.

In addition, the KNX/IoT technology developed for AAL House allows the integration of services like medicine notification, monitoring and report of eating habits, etc. Additional services for elders like water tap overflow identification and respective notification triggering or turning off the oven are also supported.

Figures 18.10 and 18.11 presentthe main control panel of the AAL House through which the aforementioned services are being monitored and controlled.

The AAL House supports also a new trend in home automation which is called *Geofencing* allowing the definition and monitoring of virtual fences within the house (as well as close surrounding areas). This is especially important for people suffering

Fig. 18.11 Ambient Assisted Living House

from dementia related diseases. In addition, the Geofencing service of the AAL House allows KNX related actions such as turning off of lights, electrical appliances, ventilation, central heating, and air-conditioning.

From a technical point of view, all the services offered by the ALL House are strongly dependent on the underlying infrastructure which combines KNX with wireless sensor technologies like the ones presented in Sect. 18.4. The heterogeneous technologies hosted by AAL House are a proof of concept of combining the worlds of KNX of Things and IoT in the context of a BAS.

18.10 Conclusion

In this paper, we present the constituent parts of a modern Building Automation Systems (BAS). Nowadays, BAS face a real challenge since their needs and their requirements have shifted from standalone automation services to solutions that will allow BAS to operate seamlessly with IoT devices.

The existence of several protocols from different manufacturers and the fact that during the next years the number of interconnected devices worldwide will be more than 50 billion pose significant challenges for modern BAS. To address those challenges, we present an overview of the existing technologies that could be employed in a BAS and we analyze their pros and cons. Based on this analysis, we propose an abstract architecture for combining KNX of Things (the most popular BAS protocol) with the IoT paradigm. The proposed architecture has been implemented in the context of a real world Ambient Assisted Living environment: a fully operational residence for supporting elders and persons with chronic diseases, where KNX/IoT devices have been employed for developing state-of-the-art services.

The work presented in this chapter is the foundation of future research in the area of BAS. In the near future, we plan to design and implement an extension of the proposed infrastructure, so as to enrich and enhance the offered services with artificial intelligence [12]. For that purpose, a cloud-based platform will be developed that will allow the transition from "smart" to "intelligent" homes and buildings.

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