

Home and Building Automation (Components and Elements)



Micaela Damron

First Edition, 2012

ISBN 978-81-323-3598-6

© All rights reserved.

Published by:

University Publications

4735/22 Prakashdeep Bldg,

Ansari Road, Darya Ganj,

Delhi - 110002

Email: info@wtbooks.com

Table of Contents

Chapter 1 - Home Automation

Chapter 2 - Building Automation

Chapter 3 - Wireless Networking and Technology

Chapter 4 - Control and Automation Protocols

Chapter 5 - HVAC

Chapter 6 - Home Automation for the Elderly and Disabled

Chapter- 1

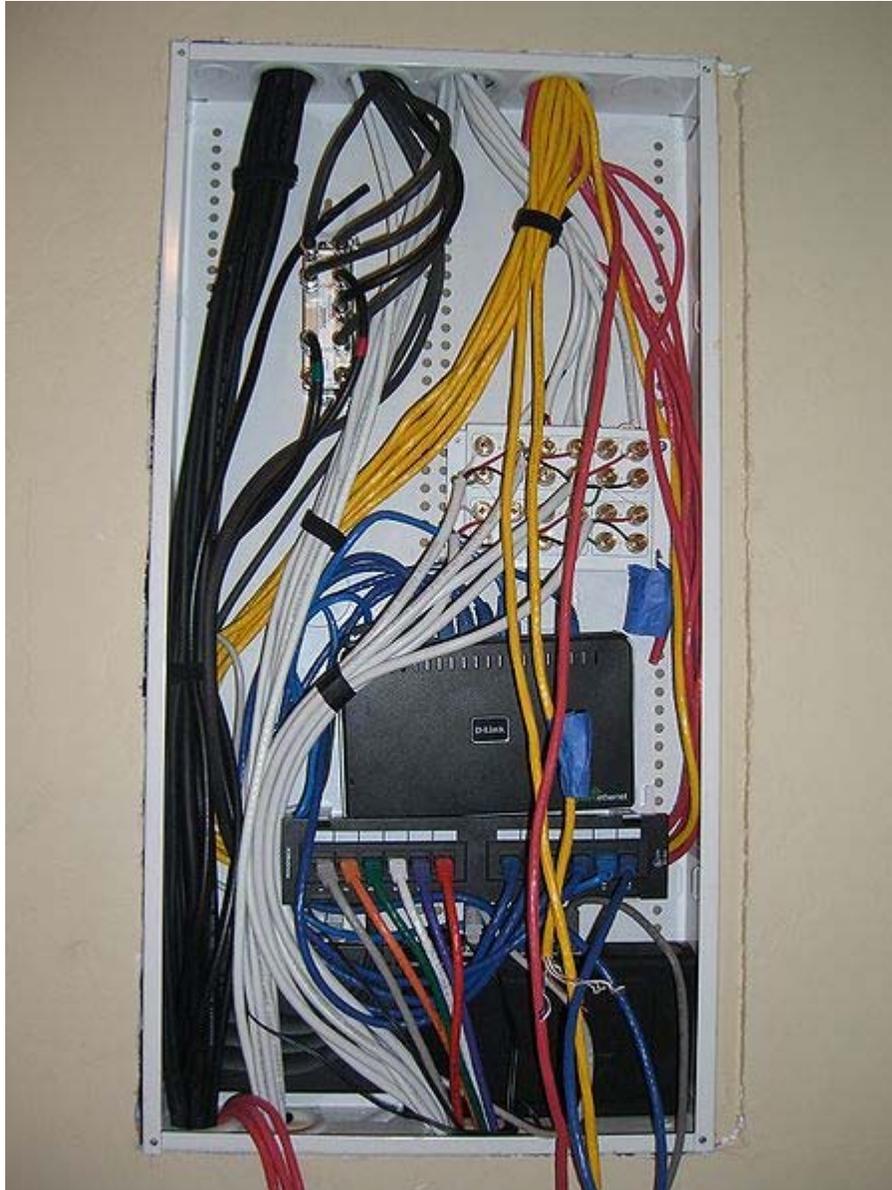
Home Automation

Home automation (also called **domotics**) is the residential extension of "building automation". It is automation of the home, housework or household activity. Home automation may include centralized control of lighting, HVAC (heating, ventilation and air conditioning), appliances, and other systems, to provide improved convenience, comfort, energy efficiency and security. Home automation for the elderly and disabled can provide increased quality of life for persons who might otherwise require caregivers or institutional care.

A home automation system integrates electrical devices in a house with each other. The techniques employed in home automation include those in building automation as well as the control of domestic activities, such as home entertainment systems, houseplant and yard watering, pet feeding, changing the ambiance "scenes" for different events (such as dinners or parties), and the use of domestic robots. Devices may be connected through a computer network to allow control by a personal computer, and may allow remote access from the internet.

Typically, a new home is outfitted for home automation during construction, due to the accessibility of the walls, outlets, and storage rooms, and the ability to make design changes specifically to accommodate certain technologies. Wireless systems are commonly installed when outfitting a pre-existing house, as they reduce wiring changes. These communicate through the existing power wiring, radio, or infrared signals with a central controller. Network sockets may be installed in every room like AC power receptacles.

Although automated *homes of the future* have been staple exhibits for World's Fairs and popular backgrounds in science fiction, complexity, competition between vendors, multiple incompatible standards and the resulting expense have limited the penetration of home automation to homes of the wealthy or ambitious hobbyists.



A typical domestic patch panel.

Overview and benefits

In modern construction in industrialized nations, homes have been wired for electrical power, telephones, TV outlets (cable or antenna), and a doorbell.

Many household tasks were automated by the development of special appliances. For instance, automatic washing machines were developed to reduce the manual labor of cleaning clothes, and water heaters reduced the labor necessary for bathing.

Other traditional household tasks, like food preservation and preparation have been automated in large extent by moving them into factory settings, with the development of pre-made, pre-packaged foods, and in some countries, such as the United States, increased reliance on commercial food preparation services, such as fast food restaurants. Volume and the factory setting allows forms of automation that would be impractical or too costly in a home setting. Standardized foods enable possible further automation of handling the food within the home.

The use of gaseous or liquid fuels, and later the use of electricity enabled increased automation in heating, reducing the labor necessary to fuel heaters and stoves. Development of thermostats allowed more automated control of heating, and later cooling.

A remote control for moving vessels and vehicles was first patented by Nikola Tesla in 1898.

World's Fairs in Chicago (1934), New York (1939) and (1964–65) depicted electrified and automated homes. In 1966 Jim Sutherland, an engineer working for Westinghouse Electric, developed a home automation system called "ECHO IV"; this was a private project and never commercialized.

With the invention of the microcontroller, the cost of electronic control fell rapidly. Remote and intelligent control technologies were adopted by the building services industry and appliance manufacturers worldwide, as they offer the end user easily accessible and/or greater control of their products.

As the amount of controllable appliances in the home rises, the ability of these devices to interconnect and communicate with each other digitally becomes a useful and desirable feature. The consolidation of control or monitoring signals from appliances, fittings or basic services is an aim of home automation.

In simple installations this may be as straightforward as turning on the lights when a person enters the room. In advanced installations, rooms can sense not only the presence of a person inside but know who that person is and perhaps set appropriate lighting, temperature, music levels or television channels, taking into account the day of the week, the time of day, and other factors.

Other automated tasks may include setting the air conditioning to an energy saving setting when the house is unoccupied, and restoring the normal setting when an occupant is about to return. More sophisticated systems can maintain an inventory of products, recording their usage through bar codes, or an RFID tag, and prepare a shopping list or even automatically order replacements.

Home automation can also provide a remote interface to home appliances or the automation system itself, via telephone line, wireless transmission or the internet, to provide control and monitoring via a smart phone or web browser.

An example of a remote monitoring in home automation could be when a smoke detector detects a fire or smoke condition, then all lights in the house will blink to alert any occupants of the house to the possible fire. If the house is equipped with a home theatre, a home automation system can shut down all audio and video components to avoid distractions, or make an audible announcement. The system could also call the home owner on their mobile phone to alert them, or call the fire department or alarm monitoring company.

System

The elements of a domotics system are:

- hardware controllers or software controllers
- sensors
- actuators

A centralized controller can be used, or multiple intelligent devices can be distributed around the home.

Interconnection

By wire:

1. optical fiber
2. cable (coaxial and twisted pair) , including:

xDSL

3. powerline, including:

X10

Universal powerline bus (UPB)

Wireless:

1. radio frequency, including:

Wi-Fi

GPRS and UMTS

Bluetooth

DECT

ZigBee

Z-Wave

ONE-NET

EnOcean

2. infrared, including:

Consumer IR

Both Wireless and Wire

1. INSTEON

Classifications of domestic network technologies

- Device interconnection:
 - Bluetooth
 - IEEE 1394 interface (FireWire)
 - IrDA
 - Universal Serial Bus (USB)
- Control and automation nets:
 - SCS BUS with OpenWebNet
 - C-Bus (protocol)
 - CEBus
 - EnOcean
 - EHS
 - INSTEON
 - KNX (European Installation Bus)
 - LonWorks
 - ONE-NET
 - Universal Powerline Bus
 - X10
 - ZigBee
- Data nets:
 - Ethernet
 - Homeplug
 - HomePNA
 - WiFi

There have been many attempts to standardise the forms of hardware, electronic and communication interfaces needed to construct a home automation system. Some standards use additional communication and control wiring, some embed signals in the existing power circuit of the house, some use radio frequency (RF) signals, and some use a combination of several methods. Control wiring is hardest to retrofit into an existing house. Some appliances include USB that is used to control it and connect it to a domotics network. Bridges translate information from one standard to another, *e.g.*, from X10 to European Installation Bus.

Tasks

HVAC

Heating, Ventilation and Air Conditioning (HVAC) solutions include temperature and humidity control. This is generally one of the most important aspects to a homeowner. An Internet-controlled thermostat, for example, can both save money and help the environment, by allowing the homeowner to control the building's heating and air conditioning systems remotely.

Lighting

Lighting control systems can be used to control household electric lights.

- Extinguish all the lights of the house
- Replace manual switching with Automation of on and off signals for any or all lights
- Regulation of electric illumination levels according to the level of ambient light available
- Change the ambient colour of lighting via control of LEDs or electronic dimmers

Natural lighting control involves controlling window shades, LCD shades, draperies and awnings.

Audio and video

This category includes audio and video switching and distribution. Multiple audio or video sources can be selected and distributed to one or more rooms.

Security

Control and integration of security systems.

With Home Automation, the consumer can select and watch cameras live from an Internet source to their home or business. Security cameras can be controlled, allowing the user to observe activity around a house or business right from a Monitor or touch panel. Security systems can include motion sensors that will detect any kind of unauthorized movement and notify the user through the security system or via cell phone.

This category also includes control and distribution of security cameras.

- Detection of possible intrusion
 - sensors of detection of movement
 - sensors of magnetic contact of door/window
 - sensors of glass breaking
 - sensors of pressure changes
- Simulation of presence.
- Detection of fire, gas leaks, water leaks
- Medical alert. Teleassistance.
- Precise and safe closing of blinds.

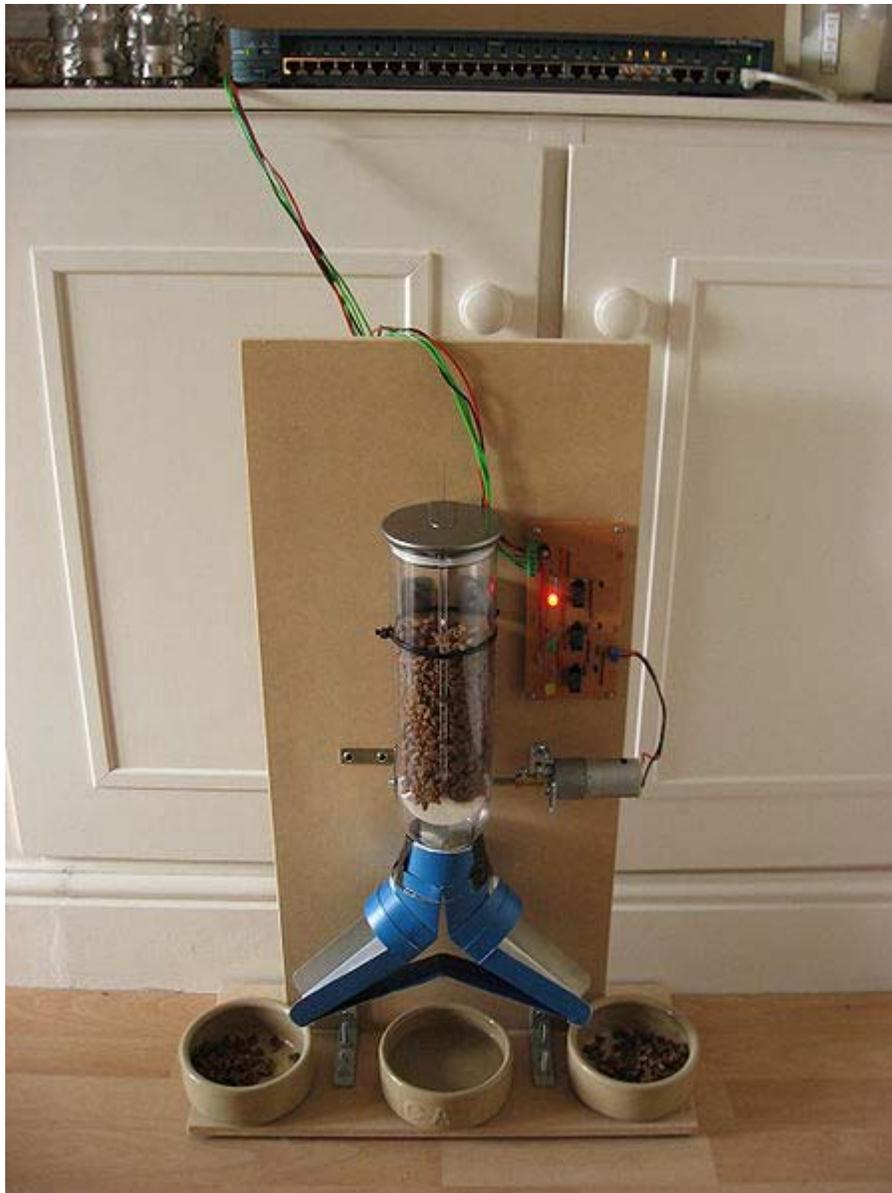
Intercoms

An intercom system allows communication via a microphone and loud speaker between multiple rooms. Integration of the intercom to the telephone, or of the video door entry system to the television set, allowing the residents to view the door camera automatically.

Robotics

- Control of home robots, using if necessary domotic electric beacon.
- Home robot communication (i.e. using WiFi) with the domotic network and other home robots.

Other systems



A homemade Internet-enabled cat feeder.

Using special hardware, almost any device can be monitored and controlled automatically or remotely, including:

- Coffee pot
- Garage door
- Pet feeding and watering
- Plant watering
- Pool pump(s) and heater, Hot tub and Spa
- Sump Pump

Costs

An automated home can be a very simple grouping of controls, or it can be heavily automated where any appliance that is plugged into electrical power is remotely controlled. Costs mainly include equipment, components, furniture, and custom installation.

Ongoing costs include electricity to run the control systems, maintenance costs for the control and networking systems, including troubleshooting, and eventual cost of upgrading as standards change. Increased complexity may also increase maintenance costs for networked devices.

Learning to use a complex system effectively may take significant time and training.

Control system security may be difficult and costly to maintain, especially if the control system extends beyond the home, for instance by wireless or by connection to the internet or other networks.

Smart Grid

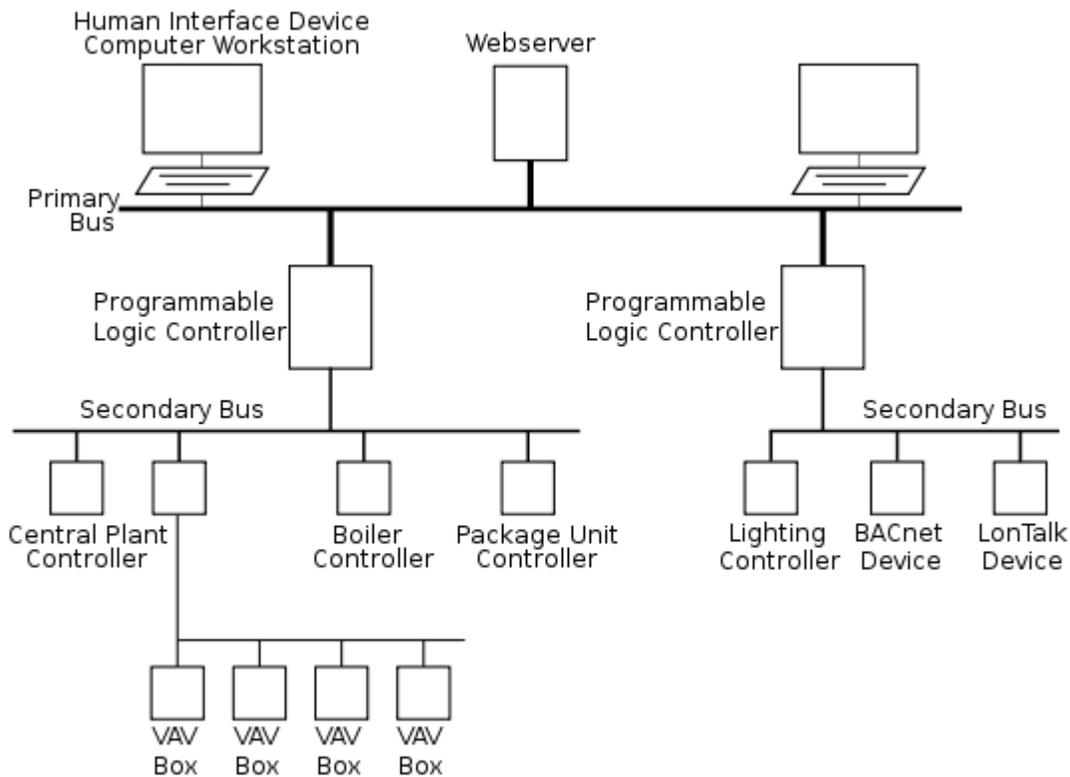
Home automation technologies are viewed as integral additions to the Smart grid. The ability to control lighting, appliances, HVAC as well as Smart Grid applications (load shedding, demand response, real-time power usage and price reporting) will become vital as Smart Grid initiatives are rolled out. Green Automation is the term coined to describe energy management strategies in home automation when data from smart grids is combined with home automation systems to use resources either at their cheapest prices or most available. For example taking advantage of high solar panel output in the middle of the day to run washing machines automatically.

Chapter- 2

Building Automation

Building automation describes the functionality provided by the control system of a building. A building automation system (BAS) is an example of a distributed control system. The control system is a computerized, intelligent network of electronic devices, designed to monitor and control the mechanical and lighting systems in a building.

BAS core functionality keeps the building climate within a specified range, provides lighting based on an occupancy schedule, and monitors system performance and device failures and provides email and/or text notifications to building engineering staff. The BAS functionality reduces building energy and maintenance costs when compared to a non-controlled building. A building controlled by a BAS is often referred to as an intelligent building system.



Topology

Most building automation networks consist of a *primary* and *secondary* bus which connect high-level controllers (generally specialized for building automation, but may be generic programmable logic controllers) with lower-level controllers, input/output devices and a user interface (also known as a human interface device).

The primary and secondary bus can be BACnet, optical fiber, ethernet, ARCNET, RS-232, RS-485 or a wireless network.

Most controllers are proprietary. Each company has its own controllers for specific applications. Some are designed with limited controls: for example, a simple Packaged Roof Top Unit. Others are designed to be flexible. Most have proprietary software that will work with ASHRAE's open protocol BACnet or the open protocol LonTalk.

Some newer building automation and lighting control solutions use wireless mesh open standards (such as ZigBee). These systems can provide interoperability, allowing users to mix-and-match devices from different manufacturers, and to provide integration with other compatible building control systems.

Inputs and outputs are either analog or digital (some companies say binary).

Analog inputs are used to read a variable measurement. Examples are temperature, humidity and pressure sensor which could be thermistor, 4-20 mA, 0-10 volt or platinum resistance thermometer (resistance temperature detector), or wireless sensors.

A digital input indicates if a device is turned on or not. Some examples of an digital input would be a 24VDC/AC signal, an air flow switch, or a volta-free relay contact (Dry Contact).

Analog outputs control the speed or position of a device, such as a variable frequency drive, a I-P (current to pneumatics) transducer, or a valve or damper actuator. An example is a hot water valve opening up 25% to maintain a setpoint.

Digital outputs are used to open and close relays and switches. An example would be to turn on the parking lot lights when a photocell indicates it is dark outside.

Infrastructure

Controller

Controllers are essentially small, purpose-built computers with input and output capabilities. These controllers come in a range of sizes and capabilities to control devices commonly found in buildings, and to control sub-networks of controllers.

Inputs allow a controller to read temperatures, humidity, pressure, current flow, air flow, and other essential factors. The outputs allow the controller to send command and control signals to slave devices, and to other parts of the system. Inputs and outputs can be either digital or analog. Digital outputs are also sometimes called discrete depending on manufacturer.

Controllers used for building automation can be grouped in 3 categories. Programmable Logic Controllers (PLCs), System/Network controllers, and Terminal Unit controllers. However an additional device can also exist in order to integrate 3rd party systems (i.e. a stand-alone AC system) into a central Building automation system).

PLC's provide the most responsiveness and processing power, but at a unit cost typically 2 to 3 times that of a System/Network controller intended for BAS applications. Terminal Unit controllers are usually the least expensive and least powerful.

PLC's may be used to automate high-end applications such as clean rooms or hospitals where the cost of the controllers is a lesser concern.

In office buildings, supermarkets, malls, and other common automated buildings the systems will use System/Network controllers rather than PLC's. Most System controllers provide general purpose feedback loops, as well as digital circuits, but lack the millisecond response time that PLC's provide.

System/Network controllers may be applied to control one or more mechanical systems such as an Air Handler Unit (AHU), boiler, chiller, etc., or they may supervise a sub-network of controllers. In the diagram above, System/Network controllers are often used in place of PLCs.

Terminal Unit controllers usually are suited for control of lighting and/or simpler devices such as a package rooftop unit, heat pump, VAV box, or fan coil, etc. The installer typically selects 1 of the available pre-programmed personalities best suited to the device to be controlled, and does not have to create new control logic.

Occupancy

Occupancy is one of 2 or more operating modes for a building automation system. Unoccupied, Morning Warmup, and Night-time Setback are other common modes.

Occupancy is usually based on time of day schedules. In Occupancy mode, the BAS aims to provide a comfortable climate and adequate lighting, often with zone-based control so that users on one side of a building have a different thermostat (or a different system, or sub system) than users on the opposite side.

A temperature sensor in the zone provides feedback to the controller, so it can deliver heating or cooling as needed.

If enabled, Morning Warmup (MWU) mode occurs prior to Occupancy. During Morning Warmup the BAS tries to bring the building to setpoint just in time for Occupancy. The BAS often factors in outdoor conditions and historical experience to optimize MWU. This is also referred to as Optimised Start.

An override is a manually-initiated command to the BAS. For example, many wall-mounted temperature sensors will have a push-button that forces the system into Occupancy mode for a set number of minutes. Where present, web interfaces allow users to remotely initiate an override on the BAS.

Some buildings rely on occupancy sensors to activate lighting and/or climate conditioning. Given the potential for long lead times before a space becomes sufficiently cool or warm, climate conditioning is not often initiated directly by an occupancy sensor.

Lighting

Lighting can be turned on, off, or dimmed with a building automation or lighting control system based on time of day, or on occupancy sensors, photosensors and timers. One typical example is to turn the lights in a space on for a half hour since the last motion was sensed. A photocell placed outside a building can sense darkness, and the time of day, and modulate lights in outer offices and the parking lot.

Lighting is also a good candidate for Demand response, with many control systems providing the ability to dim (or turn off) lights to take advantage of DR incentives and savings. If occupancy sensors are present they can also be used as burglar alarms

Air handlers

Most air handlers mix return and outside air so less temperature change is needed. This can save money by using less chilled or heated water (not all AHUs use chilled/hot water circuits). Some external air is needed to keep the building's air healthy.

Analog or digital temperature sensors may be placed in the space or room, the return and supply air ducts, and sometimes the external air. Actuators are placed on the hot and chilled water valves, the outside air and return air dampers. The supply fan (and return if applicable) is started and stopped based on either time of day, temperatures, building pressures or a combination.

Constant volume air-handling units

The less efficient type of air-handler is a "constant volume air handling unit," or CAV. The fans in CAVs do not have variable-speed controls. Instead, CAVs open and close dampers and water-supply valves to maintain temperatures in the building's spaces. They heat or cool the spaces by opening or closing chilled or hot water valves that feed their internal heat exchangers. Generally one CAV serves several spaces, but large buildings may have many CAVs.

Variable volume air-handling units

A more efficient unit is a "variable air volume (VAV) air-handling unit," or VAV. VAVs supply pressurized air to VAV boxes, usually one box per room or area. A VAV air handler can change the pressure to the VAV boxes by changing the speed of a fan or blower with a variable frequency drive or (less efficiently) by moving inlet guide vanes to a fixed-speed fan. The amount of air is determined by the needs of the spaces served by the VAV boxes.

Each VAV box supply air to a small space, like an office. Each box has a damper that is opened or closed based on how much heating or cooling is required in its space. The more boxes are open, the more air is required, and a greater amount of air is supplied by the VAV air-handling unit.

Some VAV boxes also have hot water valves and an internal heat exchanger. The valves for hot and cold water are opened or closed based on the heat demand for the spaces it is supplying. These heated VAV boxes are sometimes used on the perimeter only and the interior zones are cooling only.

A minimum and maximum CFM must be set on VAV boxes to assure adequate ventilation and proper air balance.

VAV hybrid systems

Another variation is a hybrid between VAV and CAV systems. In this system, the interior zones operate as in a VAV system. The outer zones differ in that the heating is supplied by a heating fan in a central location usually with a heating coil fed by the building boiler. The heated air is ducted to the exterior dual duct mixing boxes and dampers controlled by the zone thermostat calling for either cooled or heated air as needed.

Central plant

A central plant is needed to supply the air-handling units with water. It may supply a chilled water system, hot water system and a condenser water system, as well as transformers and auxiliary power unit for emergency power. If well managed, these can often help each other. For example, some plants generate electric power at periods with peak demand, using a gas turbine, and then use the turbine's hot exhaust to heat water or power an absorptive chiller.

Chilled water system

Chilled water is often used to cool a building's air and equipment. The chilled water system will have chiller(s) and pumps. Analog temperature sensors measure the chilled water supply and return lines. The chiller(s) are sequenced on and off to chill the chilled water supply.

Condenser water system

Cooling tower(s) and pumps are used to supply cool condenser water to the chillers. Because the condenser water supply to the chillers has to be constant, variable speed drives are commonly used on the cooling tower fans to control temperature. Proper cooling tower temperature assures the proper refrigerant head pressure in the chiller. The cooling tower set point used depends upon the refrigerant being used. Analog temperature sensors measure the condenser water supply and return lines.

Hot water system

The hot water system supplies heat to the building's air-handling unit or VAV box heating coils, along with the domestic hot water heating coils (Calorifier). The hot water system will have a boiler(s) and pumps. Analog temperature sensors are placed in the hot water supply and return lines. Some type of mixing valve is usually used to control the heating water loop temperature. The boiler(s) and pumps are sequenced on and off to maintain supply.

Alarms and security

Many building automation systems have alarm capabilities. If an alarm is detected, it can be programmed to notify someone. Notification can be through a computer, pager, cellular phone, or audible alarm.

- Common temperature alarms are: space, supply air, chilled water supply and hot water supply.
- Differential pressure switches can be placed on the filter to determine if it is dirty.
- Status alarms are common. If a mechanical device like a pump is requested to start, and the status input indicates it is off. This can indicate a mechanical failure.
- Some valve actuators have end switches to indicate if the valve has opened or not.
- Carbon monoxide and carbon dioxide sensors can be used to alarm if levels are too high.
- Refrigerant sensors can be used to indicate a possible refrigerant leak.
- Current sensors can be used to detect low current conditions caused by slipping fan belts, or clogging strainers at pumps.

At sites with several buildings, momentary power failures can cause hundreds or thousands of alarms from equipment that has shut down. Some sites are programmed so that critical alarms are automatically re-sent at varying intervals. For example, a repeating critical alarm (of a uninterpretable power supply in 'by pass') might resound at 10 minutes, 30 minutes, and every 2 to 4 hours there after until the alarms are resolved.

Security systems can be interlocked to a building automation system. If occupancy sensors are present, they can also be used as burglar alarms.

Fire and smoke alarm systems can be hard-wired to override building automation. For example: if the smoke alarm is activated, all the outside air dampers close to prevent air coming into the building, and an exhaust system can isolate

Room automation

Room automation is a subset of Building automation and like it, is the consolidation of one or systems under centralised control but in this case in just one room .

The most common example of *room automation* is corporate boardroom, presentation suites, and lecture halls, where the operation of the large number of devices that define the room function (such as Videoconferencing equipment, Video projectors, lighting control systems, Public address systems etc.) would make manual operation of the room very complex. It is common for room automation systems to employ a touchscreen as the primary way of controlling each operation.

Chapter- 3

Wireless Networking and Technology

EnOcean

EnOcean is a wireless, energy harvesting technology used primarily in building automation systems. It is not set out for international, European or national standardization; however, EnOcean GmbH is offering its technology and licenses for the patented features under license within the EnOcean Alliance framework. The concept was developed to enable batteryless sensors and switches for building automation.

EnOcean Technology

EnOcean technology is based on the energetically efficient exploitation of applied slight mechanical excitation and other potentials from the environment using the principles of energy harvesting.

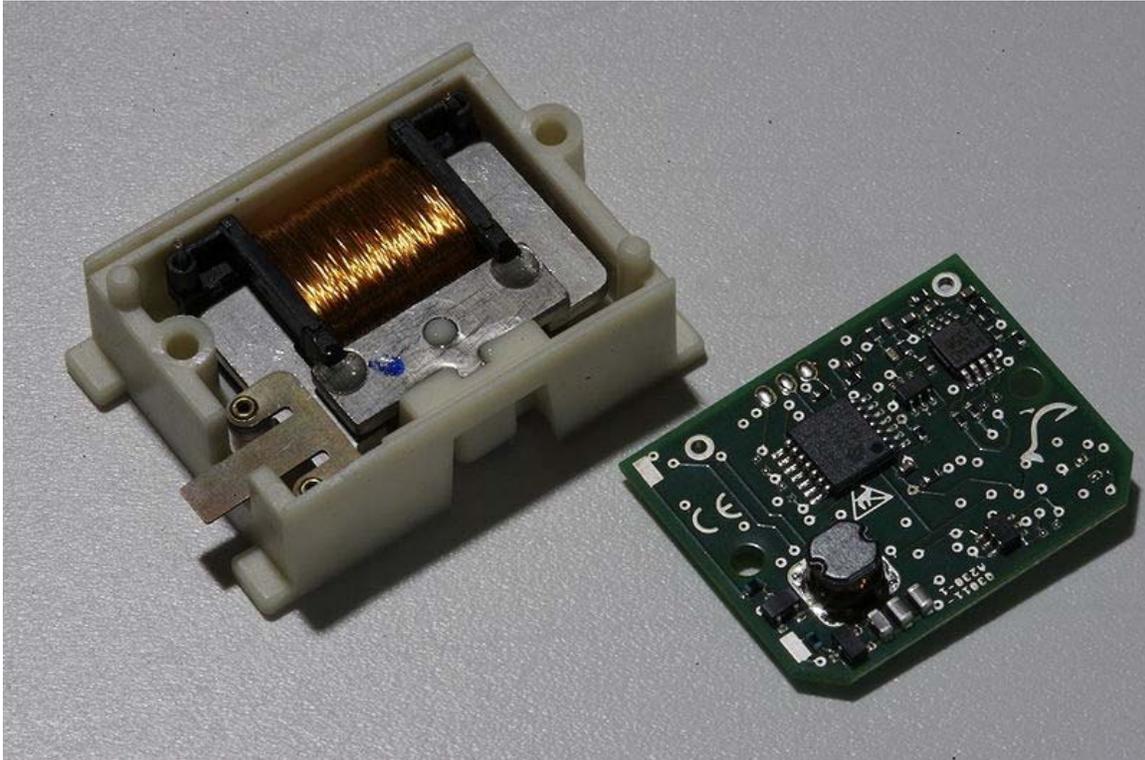


EnOcean PTM 250 Wireless & Batteryless switch

In order to transform such energy fluctuations into usable electrical energy, electromagnetic, piezogenerators, solar cells, thermocouples, and other energy converters are used.

The EnOcean products (such as sensors and radio switches) do not need a battery and are engineered to operate maintenance-free. The signals from these sensors and switches can be transmitted wireless over a distance of up to 300 meters. Early designs from the company used piezo generators, later replaced with electromagnetic energy sources to reduce the operating pressure (7 newtons), and increase the service life to 50,000 operations.

Packets of data are relatively small with the packet being only 14 bytes long and are transmitted at 120 kbit/s. RF energy is only transmitted for the 1's on the data, reducing the amount of power required. Three packets are sent at pseudo-random intervals reducing the possibility of packet collisions. Switches also transmit additional data packets on release of push-button switches, enabling other features such as light dimming to be implemented. The transmission frequency used for the devices is 868.3 MHz.



ECO 100 power generator and PTM 230 transmitter module

Application examples

One example of the technology is a battery-free wireless light switch. Advantages are that that it saves time and material by eliminating the need to install wires between the switch and device, e.g., a light, and that it also reduces noise on switched circuits, as the switching is performed locally at the load.

Another application is an audience voting system developed by EnOcean's UK distributor. Each member of the audience is given a four-button remote with an EnOcean transmitter, and the signals are decoded by a receiver connected to a computer. This avoids the need to manage batteries in many remote handsets, and each handset is uniquely identified, so the "quizmaster" or presenter can see each individual answer from each member of the audience.

EnOcean Company

EnOcean GmbH is a venture-funded spin-off company of Siemens AG founded in 2001. It is a German company headquartered in Oberhaching, near Munich, which currently employs 35 employees. It is a technology supplier of self-powered modules (transmitters, receivers, transceivers, energy converter) to companies (e.g. Siemens, Distech Controls, Zumtobel, Omnio, Osram, Wieland Electric, Peha, Thermokon, Wago, Herga), which develop and manufacture products used in building automation (light, shading, hvac), industrial automation, and automotive industry (replacement of the conventional battery in tyre pressure sensors).

The company has won awards for its performance and technology including the Bavarian Innovation Prize 2002 for its globally unique technology, the award "Technology Pioneer 2006" by the World Economic Forum and the "Top-10 Product for 2007" award by Building Green.

In July 2007, the company announced technology to allow transmitters to be powered from Peltier devices with a minimum of 2 degrees Celsius temperature difference on each side of a 15 mm square Peltier panel.

In November 2007, MK Electric, the largest manufacturer of consumer electrical fittings in the UK, adopted EnOcean technology for a new range of wireless switches.

EnOcean Alliance

A group of companies across Europe and North America including EnOcean, Texas Instruments, Omnio, Sylvania, Masco, and MK Electric formed the EnOcean Alliance in April 2008 as a non-profit, mutual benefit corporation which has the formal purpose of initially developing the specifications for the interoperability of the sensor profiles for the wireless products operating in unlicensed frequency bands and subsequently to apply for ratification as an international standard at the appropriate standardization committee, and of helping to bring about the existence of a broad range of interoperable wireless monitoring and controlling products for use in and around residential, commercial and industrial buildings.

Market research company WTRS announced that EnOcean module shipments will reach \$1.4B in 2013.

ONE-NET

ONE-NET is an open-source standard for wireless networking. ONE-NET was designed for low-cost, low-power (battery-operated) control networks for applications such as home automation, security & monitoring, device control, and sensor networks. ONE-NET is not tied to any proprietary hardware or software, and can be implemented with a

variety of low-cost off-the-shelf radio transceivers and micro controllers from a number of different manufacturers.

Wireless Transmission

ONE-NET uses UHF ISM radio transceivers and currently operates in the 868 MHz and 915 MHz frequencies with 25 channels available for use in the United States. The ONE-NET standard allows for implementation on other frequencies, and some work is being done to implement it in the 433 MHz and 2.4 GHz frequency ranges.

ONE-NET utilizes Wideband FSK (Frequency-shift keying) to encode data for transmission.

ONE-NET features a dynamic data rate protocol with a base data rate of 38.4 kbit/s. The specification allows per-node dynamic data rate configuration for data rates up to 230 kbit/s.

Network Characteristics

ONE-NET supports star, peer-to-peer, and mesh networking topologies. Star network topology can be used to lower complexity and cost of peripherals, and also simplifies encryption key management. In peer-to-peer mode, a master device configures and authorizes peer-to-peer transactions. Wireless mesh network mode allows for repeating to cover larger areas or route around dead areas.

Outdoor peer-to-peer range has been measured to over 500 m, indoor peer-to-peer range has been demonstrated from 60 m to over 100 m, and mesh mode can extend operational range to several kilometers.

Simple, block, and streaming transactions are supported.

Simple transactions typically use message types as defined by the ONE-NET protocol to exchange sensor data such as temperature or energy consumption, and control data such as on/off messages. Simple transactions use encryption techniques to avoid susceptibility to replay attacks.

Block transactions can be used to transmit larger blocks of data than simple messages. Block transactions consist of multiple packets containing up to 58 bytes per packet. Blocks transactions can transfer up to 65,535 bytes per block.

Streaming transactions are similar in format to block transactions but do not require retransmission of lost data packets.

Power Management

ONE-NET is optimized for low power consumption such as battery-powered peripherals. Low-duty-cycle battery-powered ONE-NET devices such as window sensors, moisture detectors, etc. can achieve a three to five year battery life with “AA” or "AAA" alkaline cells.

Dynamic power adjustment allows signal strength info to be used to scale back transmit power to conserve battery power. High data rates and short packet sizes minimize Transceiver On time. Further power efficiency can be gained utilizing deterministic sleep periods for client devices.

Security

By default, ONE-NET uses the Extended Tiny Encryption Algorithm (XTEA) version 2 with 32 iterations (XTEA2-32). The ONE-NET protocol provides extensions to even higher levels of encryption. Encryption is integral to the ONE-NET protocol, there are no unencrypted modes. Alternate encryption ID tag allows extension to stronger algorithms.

ONE-NET helps resist a spoofing attack or replay attack by using embedded nonces to ensure unique packets. Cryptographic nonce tracking allows source verification.

Security key update rate can be set on a per-system basis to allow greater control of security level - faster key updates increase network security.

Programmable “still operational” messages can be used to detect sensor tampering or device failure.

Hardware

ONE-NET works on a number of transceivers from manufacturers such as TI, Analog Devices, Semtech, RFM, Integration and Micrel. Transceivers that have been tested as working with ONE-NET include:

- TRC102
- XE1203F
- XE1205
- ADF7025
- IA4421
- CC1100
- MICRF505

Simple ONE-NET devices such as motion sensors have modest host processor requirements:

- 16K ROM
- 1K RAM

- 128 bytes user non-volatile memory

ONE-NET is well-suited for low-cost 8-bit and 16-bit processors and has been tested with the TI MSP430, Renesas R8C, C8051, and Freescale 68HC08 (HC08).

Open Source License

ONE-NET is available to use for free using an open source license. ONE-NET uses the OSI-approved “Simplified BSD License” which is one of the so-called permissive free software licenses.

ONE-NET website provides a variety of open source community-supported resources including:

- Schematics
- Bill of Materials
- Printed Circuit Board layouts
- Antenna designs
- Implementation examples
- Source Code
- Documentation
- User forums

Z-Wave

Z-Wave is a proprietary wireless communications protocol designed for home automation, specifically to remote control applications in residential and light commercial environments. The technology uses a low-power RF radio embedded or retrofitted into home electronics devices and systems, such as lighting, home access control, entertainment systems and household appliances.

The Z-Wave Alliance is an international consortium of manufacturers that provide interoperable Z-Wave enabled devices.

Overview

Z-Wave is a low-power wireless technology designed specifically for remote control applications. Unlike Wi-Fi and other IEEE 802.11-based wireless LAN systems that are designed primarily for high-bandwidth data flow, the Z-Wave RF system operates in the sub Gigahertz frequency range and is optimized for low-overhead commands such as on-off (as in a light switch or an appliance) and raise-lower (as in a thermostat or volume control), with the ability to include device metadata in the communications.

Because Z-Wave operates apart from the crowded 2.4 GHz frequency, it is largely unaffected by interference from common household wireless electronics that operate in

this range. Z-Wave does share a range (900MHz) used by some cell-phones and would be susceptible to interference from such devices. However, this freedom from normal household interference allows for a standardized low-bandwidth control medium that can be reliable alongside common wireless devices.

As a result of its low power consumption and low cost of manufacture, Z-Wave is easily embedded in consumer electronics products, including battery operated devices such as remote controls, smoke alarms and security sensors. Z-Wave is currently supported by over 200 manufacturers worldwide and appears in a broad range of consumer products in the U.S. and Europe.

The standard itself is not open and is available only to Zensys customers under non-disclosure agreement. Some Z-Wave product vendors have embraced the open source and hobbyist communities.

Applications

Z-Wave is a mesh networking technology where each node or device on the network is capable of sending and receiving control commands through walls or floors and use intermediate nodes to route around household obstacles or radio dead spots that might occur in the home. Z-Wave devices can work individually or in groups, and can be programmed into scenes or events that trigger multiple devices, either automatically or via remote control. Some common applications for Z-Wave include:

Remote Home Control And Management

By adding Z-Wave to home electronics such as lighting, climate and security systems, it is possible to control and monitor these household functions via remote control, based on manual or automated decisions. The control can be applied to a single device or group of devices, in a single room or zone or throughout the entire home. One of the benefits of Z-Wave over power line communication technologies is the ability to function in older houses lacking a neutral wire. Z-Wave devices can also be monitored and controlled from outside of the home by way of a gateway that combines Z-Wave with broadband Internet access.

Energy Conservation

Z-Wave is envisioned as a key enabling technology for energy management in the green home. As an example, Z-Wave-enabled thermostats are able to raise or lower automatically, based on commands from Z-Wave enabled daylight sensors. Grouped scene controls can ensure that unnecessary energy consumption is minimized by various all-off states for systems throughout the home, such as lighting, appliances and home entertainment systems.

Home Safety And Security Systems

Because Z-Wave can transceive commands based on real time conditions, and is able to control devices in intelligent groupings, it allows novel extensions of traditional home security concepts. As an example, the opening of a Z-Wave enabled door lock can deactivate a security system and turn on lights when children arrive home from school, and send a notification to a parent's PC or cell phone via the Internet. Opening a Z-Wave enabled garage door can trigger exterior and interior home lights, while a Z-Wave motion detector can trigger an outdoor security light and a webcam, which would allow the end user to monitor the home while away.

Home Entertainment

Z-Wave's ability to command multiple devices as a unified event makes it well suited for home audio and video applications. For example, a simple "Play DVD" command on the remote control could turn on the needed components, set them to the correct inputs and even lower motorized shades and dim the room lights. Z-Wave's RF technology is also well suited as an evolution of conventional infrared (IR) based remote controls for home electronics, as it is not constrained by IR's line of sight and distance limitations. In January of 2008, Zensys announced a single-chip solution that pairs Z-Wave with IR control, positioning the technology as an all encompassing solution for home remote controls.

Setting up a Z-Wave network

Z-Wave mesh networks can begin with a single controllable device and a controller. Additional devices can be added at any time, as can multiple controllers, including traditional hand-held controllers, key-fob controllers, wall-switch controllers and PC applications designed for management and control of a Z-Wave network.

A device must be "included" to the Z-Wave network before it can be controlled via Z-Wave. This process (also known as "pairing" and "adding") is usually achieved by pressing a sequence of buttons on the controller and the device being added to the network. This sequence only needs to be performed once, after which the device is always recognized by the controller. Devices can be removed from the Z-Wave network by a similar process of button strokes.

This inclusion process is repeated for each device in the system. Because the controller is learning the signal strength between the devices during the inclusion process, the devices themselves should be in their intended final location before they are added to the system.

However, once a device has been introduced into a network, it can become troublesome to remove the unit without actually having the functional unit present. A number of Z-Wave users have complained that a Z-Wave controller can be functionally destroyed by the bulb that it controls blowing and any controlling units then report errors every time a command that would affect that unit is sent, *i.e.*, group commands / scene commands / all-on / all-off, etc. The only way to restore the service to a non-error reporting state is to factory reset all controllers and then relearn all Z-Wave devices.

Z-Wave Alliance

The Z-Wave Alliance is a consortium of over 160 independent manufacturers who have agreed to build wireless home control products based on the Z-Wave standard. Principal members include Cooper Wiring Devices, Danfoss, Fakro, Ingersoll-Rand, Intermatic, Leviton, Universal Electronics, Wayne-Dalton, Z-Wave and Zensys.

Products and applications from the Z-Wave Alliance fall into all major market sectors for residential and light commercial control applications. These include lighting, HVAC and security control, as well as home theaters, automated window treatments, pool and spa controls, garage and access controls and more.

Radio specifications

Bandwidth: 9,600 bit/s or 40 kbit/s, fully interoperable

Modulation: GFSK

Range: Approximately 100 feet (or 30 meters) assuming "open air" conditions, with reduced range indoors depending on building materials, etc.

Frequency band: The Z-Wave Radio uses the 900 MHz ISM band: 908.42MHz (United States); 868.42MHz (Europe); 919.82MHz (Hong Kong); 921.42MHz (Australia/New Zealand).

Radio specifics

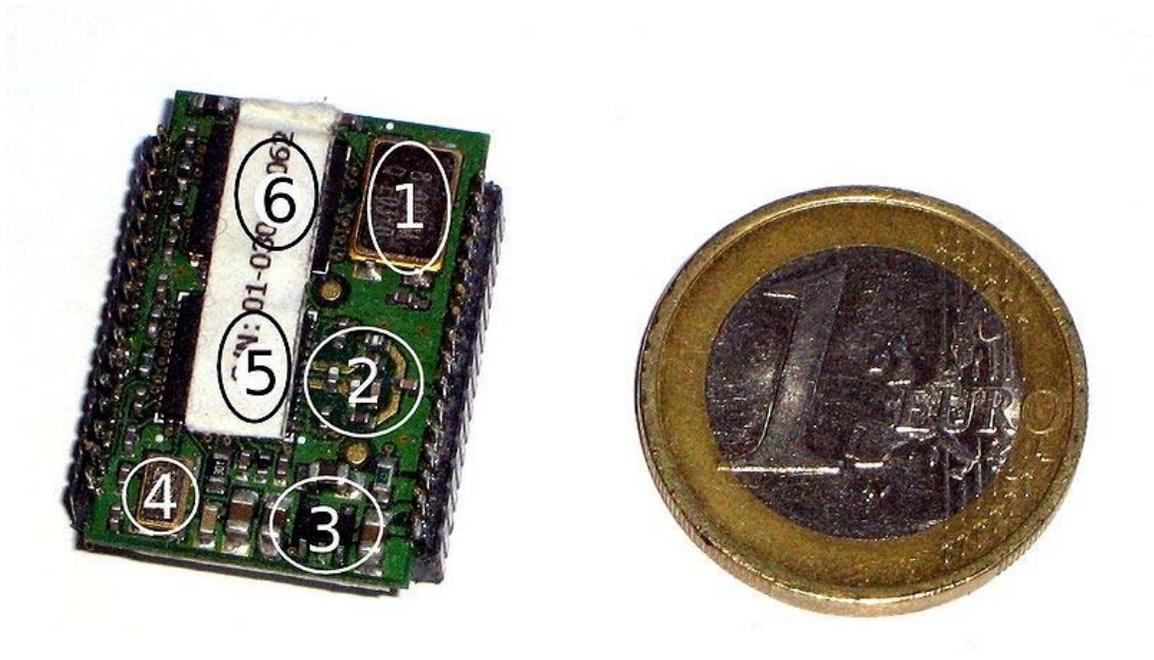
In Europe, the 868 MHz band has a 1% duty cycle limitation, meaning that a Z-Wave unit can only transmit 1% of the time. This limitation is not present in the U.S. 908 MHz band, but U.S. legislation imposes a 1 mW transmission power limit, as opposed to 25 mW in Europe. Z-Wave units can be in power-save mode and only be active 0.1% of the time, thus reducing power consumption dramatically.

Topology and routing

Z-Wave uses a Source-routed mesh network topology and has one or more master controllers that control routing and security. Devices can communicate to another by using intermediate nodes to actively route around household obstacles or radio dead spots that might occur. A message from node A to node C can be successfully delivered even if the two nodes are not within range, providing that a third node B can communicate with nodes A and C. If the preferred route is unavailable, the message originator will attempt other routes until a path is found to the "C" node. Therefore a Z-Wave network can span much farther than the radio range of a single unit; however with several of these hops a delay may be introduced between the control command and the desired result. In order

for Z-Wave units to be able to route unsolicited messages, they cannot be in sleep mode. Therefore, most battery-operated devices are not designed as repeater units. A Z-Wave network can consist of up to 232 devices with the option of bridging networks if more devices are required.

ZigBee



ZigBee module. The €1 coin, shown for size reference, is about 23 mm (0.9 inch) in diameter.

ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on the IEEE 802.15.4-2003 standard for Low-Rate Wireless Personal Area Networks (LR-WPANs), such as wireless light switches with lamps, electrical meters with in-home-displays, consumer electronics equipment via short-range radio. The technology defined by the ZigBee specification is intended to be simpler and less expensive than other WPANs, such as Bluetooth. ZigBee is targeted at radio-frequency (RF) applications that require a low data rate, long battery life, and secure networking.

Technical overview

ZigBee is a low-cost, low-power, wireless mesh networking standard. First, the low cost allows the technology to be widely deployed in wireless control and monitoring

applications. Second, the low power-usage allows longer life with smaller batteries. Third, the mesh networking provides high reliability and more extensive range.

It is not capable of powerline networking though other elements of the OpenHAN standards suite promoted by openAMI and UtilityAMI deal with communications co-extant with AC power outlets. In other words, ZigBee is intended not to support powerline networking but to interface with it at least for smart metering and smart appliance purposes. Utilities, e.g. Penn Energy, have declared the intent to require them to interoperate again via the openHAN standards.

Trademark and Alliance

The ZigBee Alliance is an association of companies working together to enable reliable, cost-effective, and low-power wirelessly networked monitoring and control products based on an open global standard.

The ZigBee Alliance is a group of companies that maintain and publish the ZigBee standard. The term **ZigBee** is a registered trademark of this group, not a single technical standard.

As per its main role, it standardizes the body that defines ZigBee, and also publishes application profiles that allow multiple OEM vendors to create interoperable products. The current list of application profiles either published or in the works are:

Released Specifications

- ZigBee Home Automation
- ZigBee Smart Energy 1.0
- ZigBee Telecommunication Services
- ZigBee Health Care
- ZigBee Remote Control

Specifications under development

- ZigBee Smart Energy 2.0
- ZigBee Building Automation
- ZigBee Retail Services

The relationship between IEEE 802.15.4 and ZigBee is similar to that between IEEE 802.11 and the Wi-Fi Alliance. The ZigBee 1.0 specification was ratified on 14 December 2004 and is available to members of the ZigBee Alliance. Most recently, the ZigBee 2007 specification was posted on 30 October 2007. The first ZigBee Application Profile, Home Automation, was announced 2 November 2007. As amended by NIST, the Smart Energy Profile 2.0 specification will remove the dependency on IEEE 802.15.4.

Device manufacturers will be able to implement any MAC/PHY, such as IEEE 802.15.4(x) and IEEE P1901, under an IP layer based on 6LoWPAN.

ZigBee operates in the industrial, scientific and medical (ISM) radio bands; 868 MHz in Europe, 915 MHz in the USA and Australia, and 2.4 GHz in most jurisdictions worldwide. The technology is intended to be simpler and less expensive than other WPANs such as Bluetooth. ZigBee chip vendors typically sell integrated radios and microcontrollers with between 60K and 256K flash memory, such as the Jennic JN5148, the Freescale MC13213, the Ember EM250, the Texas Instruments CC2530 and CC2520, the Samsung Electro-Mechanics ZBS240 and the Atmel ATmega128RFA1. Radios are also available as stand-alone components to be used with any processor or microcontroller. Generally, the chip vendors also offer the ZigBee software stack, although independent ones are also available.

Because ZigBee can activate (go from sleep to active mode) in 15 msec or less, the latency can be very low and devices can be very responsive — particularly compared to Bluetooth wake-up delays, which are typically around three seconds. Because ZigBees can sleep most of the time, average power consumption can be very low, resulting in long battery life.

The first stack release is now called *ZigBee 2004*. The second stack release is called *ZigBee 2006*, and mainly replaces the MSG/KVP structure used in 2004 with a "cluster library". The 2004 stack is now more or less obsolete.

ZigBee 2007, now the current stack release, contains two stack profiles, stack profile 1 (simply called ZigBee), for home and light commercial use, and stack profile 2 (called ZigBee Pro). ZigBee Pro offers more features, such as multi-casting, many-to-one routing and high security with Symmetric-Key Key Exchange (SKKE), while ZigBee (stack profile 1) offers a smaller footprint in RAM and flash. Both offer full mesh networking and work with all ZigBee application profiles.

ZigBee 2007 is fully backward compatible with ZigBee 2006 devices: A ZigBee 2007 device may join and operate on a ZigBee 2006 network and vice versa. Due to differences in routing options, ZigBee Pro devices must become non-routing ZigBee End-Devices (ZEDs) on a ZigBee 2006 network, the same as for ZigBee 2006 devices on a ZigBee 2007 network must become ZEDs on a ZigBee Pro network. The applications running on those devices work the same, regardless of the stack profile beneath them.

Licensing

For non-commercial purposes, the ZigBee specification is available free to the general public. An entry level membership in the ZigBee Alliance, called Adopter, provides access to the as-yet unpublished specifications and permission to create products for market using the specifications.

The click through license on the ZigBee specification requires a commercial developer to join the ZigBee Alliance. "No part of this specification may be used in development of a product for sale without becoming a member of ZigBee Alliance." This causes problems for open-source developers because the annual fee conflicts with the GNU General Public License. From the GPL v2, "b) You must cause any work that you distribute or publish, that in whole or in part contains or is derived from the Program or any part thereof, to be licensed as a whole at no charge to all third parties under the terms of this License." Since the GPL makes no distinction between commercial and non-commercial use it is impossible to implement a GPL licensed ZigBee stack or combine a ZigBee implementation with GPL licensed code. The requirement for the developer to join the ZigBee Alliance similarly conflicts with most other Free software licenses.

Uses

ZigBee protocols are intended for use in embedded applications requiring low data rates and low power consumption. ZigBee's current focus is to define a general-purpose, inexpensive, self-organizing mesh network that can be used for industrial control, embedded sensing, medical data collection, smoke and intruder warning, building automation, home automation, etc. The resulting network will use very small amounts of power — individual devices must have a battery life of at least two years to pass ZigBee certification.

Typical application areas include

- **Home Entertainment and Control** — Smart lighting, advanced temperature control, safety and security, movies and music
- **Home Awareness** — Water sensors, power sensors, energy monitoring, smoke and fire detectors, smart appliances and access sensors
- **Mobile Services** — m-payment, m-monitoring and control, m-security and access control, m-healthcare and tele-assist
- **Commercial Building** — Energy monitoring, HVAC, lighting, access control
- **Industrial Plant** — Process control, asset management, environmental management, energy management, industrial device control, machine-to-machine (M2M) communication

Device types

There are three different types of ZigBee devices:

- *ZigBee coordinator (ZC)*: The most capable device, the coordinator forms the root of the network tree and might bridge to other networks. There is exactly one

- ZigBee coordinator in each network since it is the device that started the network originally. It is able to store information about the network, including acting as the Trust Centre & repository for security keys.
- *ZigBee Router (ZR)*: As well as running an application function, a router can act as an intermediate router, passing on data from other devices.
 - *ZigBee End Device (ZED)*: Contains just enough functionality to talk to the parent node (either the coordinator or a router); it cannot relay data from other devices. This relationship allows the node to be asleep a significant amount of the time thereby giving long battery life. A ZED requires the least amount of memory, and therefore can be less expensive to manufacture than a ZR or ZC.

Protocols

The protocols build on recent algorithmic research (Ad-hoc On-demand Distance Vector, neuRFon) to automatically construct a low-speed ad-hoc network of nodes. In most large network instances, the network will be a cluster of clusters. It can also form a mesh or a single cluster. The current profiles derived from the ZigBee protocols support beacon and non-beacon enabled networks.

In non-beacon-enabled networks (those whose beacon order is 15), an unslotted CSMA/CA channel access mechanism is used. In this type of network, ZigBee Routers typically have their receivers continuously active, requiring a more robust power supply. However, this allows for heterogeneous networks in which some devices receive continuously, while others only transmit when an external stimulus is detected. The typical example of a heterogeneous network is a wireless light switch: The ZigBee node at the lamp may receive constantly, since it is connected to the mains supply, while a battery-powered light switch would remain asleep until the switch is thrown. The switch then wakes up, sends a command to the lamp, receives an acknowledgment, and returns to sleep. In such a network the lamp node will be at least a ZigBee Router, if not the ZigBee Coordinator; the switch node is typically a ZigBee End Device.

In beacon-enabled networks, the special network nodes called ZigBee Routers transmit periodic beacons to confirm their presence to other network nodes. Nodes may sleep between beacons, thus lowering their duty cycle and extending their battery life. Beacon intervals may range from 15.36 milliseconds to $15.36 \text{ ms} * 2^{14} = 251.65824 \text{ seconds}$ at 250 kbit/s, from 24 milliseconds to $24 \text{ ms} * 2^{14} = 393.216 \text{ seconds}$ at 40 kbit/s and from 48 milliseconds to $48 \text{ ms} * 2^{14} = 786.432 \text{ seconds}$ at 20 kbit/s. However, low duty cycle operation with long beacon intervals requires precise timing, which can conflict with the need for low product cost.

In general, the ZigBee protocols minimize the time the radio is on so as to reduce power use. In beaconing networks, nodes only need to be active while a beacon is being transmitted. In non-beacon-enabled networks, power consumption is decidedly asymmetrical: some devices are always active, while others spend most of their time sleeping.

Except for the Smart Energy Profile 2.0, which will be MAC/PHY agnostic, ZigBee devices are required to conform to the IEEE 802.15.4-2003 Low-Rate Wireless Personal Area Network (WPAN) standard. The standard specifies the lower protocol layers—the physical layer (PHY), and the media access control (MAC) portion of the data link layer (DLL). This standard specifies operation in the unlicensed 2.4 GHz (worldwide), 915 MHz (Americas) and 868 MHz (Europe) ISM bands. In the 2.4 GHz band there are 16 ZigBee channels, with each channel requiring 5 MHz of bandwidth. The center frequency for each channel can be calculated as, $F_C = (2405 + 5 * (ch - 11))$ MHz, where $ch = 11, 12, \dots, 26$.

The radios use direct-sequence spread spectrum coding, which is managed by the digital stream into the modulator. BPSK is used in the 868 and 915 MHz bands, and OQPSK that transmits four bits per symbol is used in the 2.4 GHz band. The raw, over-the-air data rate is 250 kbit/s per channel in the 2.4 GHz band, 40 kbit/s per channel in the 915 MHz band, and 20 kbit/s in the 868 MHz band. Transmission range is between 10 and 75 meters (33 and 246 feet) and up to 1500 meters for zigbee pro, although it is heavily dependent on the particular environment. The output power of the radios is generally 0 dBm (1 mW).

The basic channel access mode is "carrier sense, multiple access/collision avoidance" (CSMA/CA). That is, the nodes talk in the same way that people converse; they briefly check to see that no one is talking before they start. There are three notable exceptions to the use of CSMA. Beacons are sent on a fixed timing schedule, and do not use CSMA. Message acknowledgments also do not use CSMA. Finally, devices in Beacon Oriented networks that have low latency real-time requirements may also use Guaranteed Time Slots (GTS), which by definition do not use CSMA.

ZigBee RF4CE

On March 3, 2009 the RF4CE (Radio Frequency for Consumer Electronics) Consortium agreed to work with the ZigBee Alliance to jointly deliver a standardized specification for radio frequency-based remote controls. ZigBee RF4CE is designed to be deployed in a wide range of remotely-controlled audio/visual consumer electronics products, such as TVs and set-top boxes. It promises many advantages over existing remote control solutions, including richer communication and increased reliability, enhanced features and flexibility, interoperability, and no line-of-sight barrier.

Software and hardware

The software is designed to be easy to develop on small, inexpensive microprocessors. The radio design used by ZigBee has been carefully optimized for low cost in large scale production. It has few analog stages and uses digital circuits wherever possible.

Even though the radios themselves are inexpensive, the ZigBee Qualification Process involves a full validation of the requirements of the physical layer. This amount of concern about the Physical Layer has multiple benefits, since all radios derived from that

semiconductor mask set would enjoy the same RF characteristics. On the other hand, an uncertified physical layer that malfunctions could cripple the battery lifespan of other devices on a ZigBee network. Where other protocols can mask poor sensitivity or other esoteric problems in a fade compensation response, ZigBee radios have very tight engineering constraints: they are both power and bandwidth constrained. Thus, radios are tested to the ISO 17025 standard with guidance given by Clause 6 of the 802.15.4-2006 Standard. Most vendors plan to integrate the radio and microcontroller onto a single chip getting smaller devices .

History

- ZigBee-style networks began to be conceived around 1998, when many installers realized that both WiFi and Bluetooth were going to be unsuitable for many applications. In particular, many engineers saw a need for self-organizing ad-hoc digital radio networks.
- The IEEE 802.15.4-2003 standard was completed in May 2003 and has been superseded by the publication of IEEE 802.15.4-2006.
- In the summer of 2003, Philips Semiconductors, a major mesh network supporter, ceased the investment. Philips Lighting has, however, continued Philips' participation, and Philips remains a promoter member on the ZigBee Alliance Board of Directors.
- The ZigBee Alliance announced in October 2004 that the membership had more than doubled in the preceding year and had grown to more than 100 member companies, in 22 countries. By April 2005 membership had grown to more than 150 companies, and by December 2005 membership had passed 200 companies.
- The ZigBee specifications were ratified on 14 December 2004.
- The ZigBee Alliance announces public availability of Specification 1.0 on 13 June 2005, known as ZigBee 2004 Specification.
- The ZigBee Alliance announces the completion and immediate member availability of the enhanced version of the ZigBee Standard in September 2006, known as ZigBee 2006 Specification.
- During the last quarter of 2007, ZigBee PRO, the enhanced ZigBee specification was finalized.

Origin of ZigBee name

The name of the brand is originated with reference to the behaviour of honey bees after their return to the beehive.

Digital Enhanced Cordless Telecommunications



The base unit and handset of a British Telecom DECT cordless telephone

Digital Enhanced Cordless Telecommunications, usually known by the acronym **DECT**, is a digital communication standard, which is primarily used for creating cordless phone systems. It originated in Europe, where it is the universal standard, replacing earlier cordless phone standards, such as 900 MHz CT1 and CT2.

Beyond Europe, it has been adopted by Australia, and most countries in Asia and South America. North American adoption was delayed by United States radio frequency regulations. This forced development of a variation of DECT, called DECT 6.0, using a slightly different frequency range; the technology is nearly identical, but the frequency difference makes the technology inoperable with other compatible systems in other areas, even from the same manufacturer. DECT has almost universally replaced other standards in most countries where it is used, with the exception of North America.

DECT is used primarily in home and small office systems, but is also available in many PBX systems for medium and large businesses. DECT can also be used for purposes

other than cordless phones. Voice applications, such as baby monitors, are becoming common. Data applications also exist, but have been eclipsed by Wi-Fi. 3G cellular also competes with both DECT and Wi-Fi for both voice and data.

DECT handsets and bases from different manufacturers typically work together at the most basic level of functionality: making and receiving calls. The DECT standard includes a standardized interoperability profile for simple telephone capabilities, called GAP, which most manufacturers implement. The standard also contains several other interoperability profiles, for data and for radio local-loop services.

Application

The DECT standard fully specifies a means for a portable unit, such as a cordless telephone, to access a fixed telecoms network via radio. But, unlike the GSM standards, does not specify any internal aspects of the fixed network itself. Connectivity to the fixed network (which may be of many different kinds) is done through a base station or "Radio Fixed Part" to terminate the radio link, and a gateway to connect calls to the fixed network. In most cases the gateway connection is to the public switched telephone network or telephone jack, although connectivity with newer technologies such as Voice over IP has become available. There are also other devices such as some baby monitors utilizing DECT, and in these devices there is no gateway functionality.

The DECT standard originally envisaged three major areas of application:

- Domestic cordless telephony, using a single base station to connect one or more handsets to the public telecoms network.
- Enterprise premises cordless PABXs and wireless LANs, using many base stations for coverage. Calls continue as users move between different coverage cells, through a mechanism called handover. Calls can be both within the system and to the public telecoms network.
- Public access, using large numbers of base stations to provide high capacity building or urban area coverage as part of a public telecoms network.

Of these, the domestic application (cordless home telephones) has been extremely successful. The enterprise PABX market had some success, and all the major PABX vendors have offered DECT access options. The public access application did not succeed, since public cellular networks rapidly out-competed DECT by coupling their ubiquitous coverage with large increases in capacity and continuously falling costs. There has been only one major installation of DECT for public access: in early 1998 Telecom Italia launched a DECT network known as "Fido" after much regulatory delay, covering major cities in Italy. The service was promoted for only a few months and, having peaked at 142,000 subscribers, was shut down in 2001.

DECT has also been used for Fixed Wireless Access as a substitute for copper pairs in the "last mile" in countries such as India and South Africa. By using directional antennas and sacrificing some traffic capacity, cell coverage could extend to over 10 km. In Europe the

power limit laid down for use of the DECT spectrum (250 mW peak) was expressed in ERP, rather than the more commonly-used EIRP, permitting the use of high-gain directional antennas to produce much higher EIRP and hence long ranges.

The standard is also used in electronic cash terminals, traffic lights, and remote door openers.

VoIP/IP-DECT

In business, DECT has become an essential part of many PABX installations with manufacturer's proprietary methods of supporting PABX features over the DECT standard. Since the onset of the migration from TDM PBXs to VoIP and VoIP hybrid solutions, manufacturers such as Lantiq, Ascom Wireless Solutions, Aastra Technologies, Philips, Avaya, RTX Telecom, and Polycom have developed IP-DECT solutions where the backhaul from the base station is VoIP (H.323 or SIP) while the handset loop is still DECT. These solutions are sometimes restricted by the cost of the base station but may be economical where the concentration of users is high. PBX networking vendors such as Cisco promote the adoption of handsets that use VoIP over local Wifi as the replacement for DECT, but this imposes significant overhead on the design and complexity of the WiFi network in order to provide roaming, coverage and reservation of bandwidth, not to mention quality of service. However, this avoids the need for a separate DECT radio network. Other potential competitors for office installations include the Personal Handy-phone System (popular in Asia), and the use of private calls in a local microcell (using a cellular phone technology).

Technical development and adoption

The DECT standard was developed by ETSI in several phases, the first of which took place between 1988 and 1992 when the first round of standards were published. These were the ETS 300-175 series in 9 parts defining the air interface, and ETS 300-176 defining how the units should be type approved. A technical report, ETR-178, was also published to explain the standard. Subsequent standards were developed and published by ETSI to cover interoperability profiles and standards for testing.

Initially named "Digital European Cordless Telephone" at its launch by CEPT in November 1987, following a suggestion by Enrico Tosato of Italy, its name was soon changed to "Digital European Cordless Telecommunications" to reflect its broader range of application, including data services. In 1995, due to its more global usage, the name was changed from "European" to "Enhanced." It is an ETSI standard for digital portable phones (cordless home telephones), commonly used for domestic or corporate purposes. It is recognised by the ITU as fulfilling the IMT-2000 requirements and thus qualifies as a 3G system. Within the IMT-2000 group of technologies, DECT is referred to as **IMT-2000 Frequency Time (IMT-FT)**

DECT was developed by ETSI but has since been adopted by many countries all over the world. The original DECT frequency band (1880 MHz–1900 MHz) is used in all countries in Europe. Outside Europe, it is used in most of Asia, Australia and South America. In the United States, the Federal Communications Commission in 2005 changed channelization and licensing costs in a nearby band (1920 MHz–1930 MHz, or 1.9 GHz), known as Unlicensed Personal Communications Services (UPCS), allowing DECT devices to be sold in the U.S. with only minimal changes. These channels are reserved exclusively for voice communication applications and therefore are less likely to experience interference from other wireless devices such as baby monitors and wireless networks.

Features

Typical abilities of a domestic DECT Generic Access Profile (GAP) system include:

- Multiple handsets to one base station and one phone line socket. This allows several cordless telephones to be placed around the house, all operating from the same telephone jack. Additional handsets have a battery charger station which does not plug into the telephone system. Handsets can in many cases be used as intercoms, communicating between each other, and sometimes as walkie-talkies, intercommunicating without telephone line connection.
- Interference-free wireless operation to around 100 metres (109 yards) outdoors, much less indoors when separated by walls. Operates clearly in common congested domestic radio traffic situations, for instance, generally immune to interference from other DECT systems, Wi-Fi networks, video senders, Bluetooth technology, baby monitors and other wireless devices.
- Talk-time of several hours and standby time of several days on one battery charge.

Some systems offer:

- A longer range between the telephone and base station (usable further from the base)
- Extended battery talk-time, sometimes up to 24 hours

Technical properties

Some DECT properties:

- Audio codec: G.726
- Net bit rate: 32 kbit/s

- Frequency: 1880 MHz–1900 MHz in Europe, 1900 MHz-1920 MHz in China, 1910 MHz-1930 MHz in Latin America and 1920 MHz–1930 MHz in the US and Canada
- Carriers: 10 (1,728 kHz spacing) in Europe, 5 (1,728 kHz spacing) in the US
- Time slots: 2 x 12 (up and down stream)
- Channel allocation: dynamic
- Average transmission power: 10 mW (250 mW peak) in Europe, 4 mW (100 mW peak) in the US

The DECT physical layer uses:

- Frequency division multiple access (FDMA),
- Time division multiple access (TDMA) and
- Time division duplex (TDD)

This means that the radio spectrum is divided into physical channels in two dimensions: frequency and time.

The maximum allowed power for portable equipment as well as base stations is 250 mW. A portable device radiates an average of about 10 mW during a call as it is only using one of 24 time slots to transmit.

The DECT media access control layer controls the physical layer and provides connection oriented, connectionless and broadcast services to the higher layers.

The DECT data link layer uses LAPC (Link Access Protocol Control), a specially designed variant of the ISDN data link protocol called LAPD. They are based on HDLC.

The DECT network layer always contains the following protocol entities:

- Call Control (CC)
- Mobility Management (MM)

Optionally it may also contain others:

- Call Independent Supplementary Services (CISS)
- Connection Oriented Message Service (COMS)
- Connectionless Message Service (CLMS)

All these communicate through a Link Control Entity (LCE).

The call control protocol is derived from ISDN DSS1, which is a Q.931 derived protocol. Many DECT-specific changes have been made. The mobility management protocol includes many elements similar to the GSM protocol, but also includes elements unique to DECT.

Unlike the GSM protocol, the DECT network specifications do not define cross-linkages between the operation of the entities (e.g. Mobility Management and Call Control). The architecture presumes that such linkages will be designed into the interworking unit that connects the DECT access network to whatever mobility-enabled fixed network is involved. By keeping the entities separate, the handset is capable of responding to any combination of entity traffic, and this creates great flexibility in fixed network design without breaking full interoperability.

DECT GAP is an interoperability profile for DECT. The intent is that two different products from different manufacturers that both conform not only to the DECT standard, but also to the GAP profile defined within the DECT standard, are able to interoperate for basic calling. The DECT standard includes full testing suites for GAP, and GAP products on the market from different manufacturers are in practice interoperable for the basic functions.

Security

The DECT media access control layer also provides encryption services with the DECT Standard Cipher (DSC). The encryption is fairly weak, using a 35-bit initialization vector and encrypting the voice stream with 64-bit encryption.

The security algorithm has been broken. Another attack involves impersonating a DECT base station, which allows calls to be listened to, recorded, and re-routed to a different destination.

DECT for data networks

Other interoperability profiles exist in the DECT suite of standards, and in particular the DPRS (DECT Packet Radio Services) bring together a number of prior interoperability profiles for the use of DECT as a wireless LAN and wireless internet access service. With good range (up to 200 m indoors and 6 km using directional antennae outdoors), dedicated spectrum, high interference immunity, open interoperability and data speeds of around 500 kbit/s, DECT appeared at one time to be a superior alternative to Wi-Fi. The protocol capabilities built into the DECT networking protocol standards were particularly good at supporting fast roaming in the public space, between hotspots operated by competing but connected providers. The first DECT product to reach the market, Olivetti's Net³, was a wireless LAN, and German firms Dosch & Amand and Hoeft & Wessel built niche businesses on the supply of data transmission systems based on DECT.

However, the timing of the availability of DECT, in the mid 1990s, was too early to find wide application for wireless data outside niche industrial applications. Whilst contemporary providers of Wi-Fi struggled with the same issues, providers of DECT retreated to the more immediately lucrative market for cordless telephones. A key weakness was also the inaccessibility of the U.S. market, due to FCC spectrum restrictions at that time. By the time mass applications for wireless Internet had emerged,

and the U.S. had opened up to DECT, well into the new century, the industry had moved far ahead in terms of performance and DECT's time as a wireless data transport had passed.

Radio links

DECT operates in the 1880–1900 MHz band and defines ten channels from 1881.792 MHz to 1897.344 MHz with a band gap of 1728 kHz. Each base station frame provides 12 duplex speech channels, with each time slot occupying any channel. DECT operates in multicarrier/TDMA/TDD structure. DECT also provides Frequency-hopping spread spectrum over TDMA/TDD structure. If frequency-hopping is avoided, each base station can provide up to 120 channels in the DECT spectrum before frequency reuse. Each time slot can be assigned to a different channel in order to exploit advantages of frequency-hopping and to avoid interference from other users in asynchronous fashion.

DECT 6.0

The "6.0" in **DECT 6.0** does not specify a spectrum band, but is a marketing term coined by Rick Krupka, Director of Cordless Products at Siemens, for DECT devices manufactured for use in the U.S. and Canada. Although DECT 6.0 operates at 1.9 GHz, he realized the term **DECT 1.9** might have confused customers who equate larger numbers (such as the **2.4** and **5.8** in existing 2.4 GHz and 5.8 GHz cordless telephones) with later products. The DECT and DECT 6.0 technologies are nearly identical, except for operating frequency.

As DECT 6.0 does not operate in the 2.4 GHz ISM band, it is not subject to the interference arising in this band from its use by 802.11b and 802.11g WiFi, and 2.4 GHz cordless phones.

XDECT R

XDECT R is a Uniden technology for extending the range of DECT phones (apparently indefinitely) by using multiple repeater stations. The company has demonstrated the technology to a 2.2 kilometre range in Australia. XDECT R is not a "technology" but a marketing term used by Uniden to differentiate their products for the consumer.

Health and safety

DECT is a microwave technology, with science similar to mobile phones, baby monitors, Wi-Fi, and other cordless telephone technologies. As with all such technologies, consensus is that there are negligible health effects from the microwave radiation. Most studies have shown either no health effects, or have been inconclusive. Nevertheless, there has been persistent controversy over their health safety, and some national and international agencies have made specific recommendations about exposure.

Chapter- 4

Control and Automation Protocols

Bus SCS

SCS is an acronym for “*Sistema Cablaggio Semplificato*” (“Simplified Wiring System”). It uses a fieldbus network protocol and has applications in the field of home automation and building automation.

General Features

An SCS bus is based on a sheathed twisted pair formed of two flexible conductors; these are braided and unshielded with isolation 300/500V – according to the rules adopted by CEI (Italian Electrotechnical Committee).

Communication

Across the SCS bus four different types of signals are transmitted in frequency modulation

- Electricity Supply
- Data
- Sound
- Video

The transmission protocol is the CSMA/CA.

Functions

Through the SCS bus you have the following functions:

- Automation
- Sound diffusion

- Energy management
- Thermoregulation
- Video intercom

All the listed functions share the same technology and the same procedures for configuration / installation.

Certifications

Devices connected to the SCS bus are IMQ-certified and comply with these product standards (International Electrotechnical Commission (IEC) EN 50428 - IEC EN 60669-1/A1 - IEC EN 60669-2-1 - IEC EN 50090-2-2 - IEC EN 50090-2-3).

Integration

You can interact with the SCS bus through a gateway and an open high-level protocol called OpenWebNet.

These gateways are bidirectional; they translate SCS frames into OpenWebNet frames, and the other way round.

OpenWebNet

OpenWebNet is a Communication Protocol developed by Bticino since 2000.

OpenWebNet Protocol allow a “high level” interaction between a remote unit and Bus SCS of MyHome domotic system.

Latest protocol evolution has been improved to allow interaction with well known home automation systems like KNX and DMX512-A system, by using appropriate gateways.

The *OpenWebNet* protocol is disclosed on MyOpen community.

OpenWebNet Protocol

The protocol is thought to being independent from the used technology. For example it's possible to use a supervisor software connected via Ethernet, via serial RS-232 or via USB to a gateway that is directly connected to a domotic system.

Everyone can require protocol message extension. It's enough to propose your own RFC. It will be examined and disclosed if it respects *OpenWebNet* syntax.

Syntax

An *OpenWebNet* message is structured with variable length fields separated by the special character '*' and closed by '##'.

The characters admitted in the fields are numbers and the character “#”.

The structure of a message is therefore:

- field1*field2*... *fieldN##

The following fields are admitted: WHO WHERE WHAT DIMENSION VALUE

WHO

It characterizes the domotic system function to which the OpenWebNet message is referred.

For example: WHO = 1, characterizes the messages for lighting system management.

WHERE

It characterizes the set of objects to which the OpenWebNet message is referred. It can be a single object, a group of objects, a specific environment, the entire system, etc.

For every WHO (and therefore for every function) there is a specified WHERE table.

The tag WHERE can also contain optional parameters: WHERE#PAR1#PAR2... #PARn.

Example of where: all the lights of group 1, sensor 2 of zone 1 of alarm system, etc.

WHAT

It characterizes an action to do or a status to read. For every WHO (and therefore for every function) there is a specific WHAT table.

The field WHAT can also contain optional parameters: WHAT#PAR1#PAR2... #PARn.

Example of actions: switch ON light, dimmer to 75%, switch DOWN shutter, radio ON, etc. Example of status: light ON, active alarm, battery unload, etc.

DIMENSION

Is a range of value that characterizes the dimension of the object to which the message is referred. For every WHO (and therefore for every function) there is a specific DIMENSION table.

It's possible to require/to read/to write the value of one dimension. Every dimension has a prefixed number of values, described in VALUE field.

Example of dimension: sensor temperature, loudspeaker volume, firmware version of a device, etc.

VALUE

It characterizes the read/written value of a written/required/read dimension.

Message

There are 4 types of OpenWebNet Message:

Command / Status Message

Status Request Message

Request/Read/Write Dimension Message

Acknowledge Message

Command / Status Message

*WHO*WHAT*WHERE##

Status Request Message

*#WHO*WHERE##

Request/Read/Write Dimension Message Request:

*#WHO*WHERE*DIMENSION##

Read:

*#WHO*WHERE*DIMENSION*VALUE1*...*VALUEn##

Write:

*#WHO*WHERE*#DIMENSION*VALUE1*...*VALUEn##

Acknowledge Message ACK:

*#*1##

NACK:

*#*0##

Gateway OpenWebNet

It's possible to interact with the SCS home automation bus by using a specific gateway.

There are two typologies of gateways that allow a connection to the field bus by using different standard protocols:

- Gateway Ethernet (Linux based)
- Gateway USB / RS232

Gateway Ethernet

The current implementation by BTicino is also an embedded web server. It works as a translator between OpenWebNet messages via TCP/IP and the SCS messages transmitted on the SCS bus.

Actually it is possible to control three different kinds of buses:

- BUS SCS
- KNX
- DMX

Gateway USB / RS232

The gateway is an interface that works as a translator between the OpenWebNet messages transmitted on USB or Serial and the SCS messages transmitted on the SCS bus.

Example

OpenWebNet message examples

Command Message

Switch Off of light 77

*1*0*77##

WHO = 1 WHAT = 0 WHERE = 77

Status Message

Scenario 1 of scenario unit 23 activated.

*0*1*23##

WHO = 0 WHAT = 1 WHERE = 23

Request status message

Status request of probe 1

*#4*1##

WHO = 4 WHERE = 1

Request Dimension Message

Request of Temperature Measured, probe 44

*#4*44*0##

WHO = 4 WHERE = 44 DIMENSION = 0

Read Dimension Message

Temperature Measured, probe 44

*#4*44*0*0251*2##

WHO = 4 WHERE = 44 DIMENSION = 0 VALUE1 = 0251 (T=+25,1°C) VALUE2 = 2
(System in "cooling mode")

Write Dimension Message

Volume set at 50%, environment 2

#16#2*#1*16*##

WHO = 4 WHERE = #1 DIMENSION = 1 VALUE1 = 16

C-Bus (protocol)

C-Bus is a proprietary communications protocol for home and building automation that can handle cable lengths up to 1000 meter using Cat.5 cable. It is used in Australia, New

Zealand, Asia, the Middle East, Russia, USA, South Africa, the UK and other parts of Europe including Greece and Romania. C-Bus was created by Clipsal's *Clipsal Integrated Systems* division for use with its brand of home automation and building lighting control system. C-Bus has recently become available in the USA under the 'SquareD Clipsal' brand name.

C-Bus is used in the control of domotics, or home automation systems, as well as commercial building lighting control systems. Unlike the more common X10 protocol which uses a signal imposed upon the AC power line, C-Bus uses a dedicated low-voltage cable or two-way wireless network to carry command and control signals. This improves the reliability of command transmission and makes C-Bus far more suitable for large, commercial applications than X10.

C-Bus System

The C-Bus System can be used to control lighting and other electrical systems and products via remote control and can also be interfaced to a home security system, AV products or other electrical items. The C-Bus system is available in a wired version and a wireless version, with a gateway available to allow messages to be sent between wired and wireless networks.

The wired C-Bus system uses a standard category 5 UTP (Unshielded Twisted Pair) cable as its network communications cable. Clipsal manufacture a specific category 5 cable for use within electrical distribution panels. This cable has a pink outer sheath which is rated to ensure adequate electrical isolation between the mains voltages found in distribution panels and the extra low voltage C-Bus. Outside of distribution panels standard category 5 UTP cable can be used.

The category 5 C-Bus network wiring uses a free topology architecture. The maximum length of cable used on a C-Bus network is 1000 metres; however this is easily extended using C-Bus Network Bridges. Up to 100 units can be installed on a C-Bus network and this can also be extended using Network Bridges.

The maximum number of C-Bus networks in one installation is 255 (note that this limitation does not apply if a C-Bus Ethernet Interface is utilised, the system size is then limited to IP Addressing only). The maximum number of networks connected in series to the local network via Network Bridges is seven (i.e. using six network bridges).

Each standard C-Bus unit requires 18mA @ 15-36Vdc to operate. However some C-Bus units require up to 40mA.

More than one C-Bus power supply can be connected to a C-Bus network to provide sufficient power to the C-Bus units, the C-Bus power supplies will share the load evenly.

Each C-Bus network requires a network burden. This network burden can be enabled on C-Bus output units through software or a hardware burden can be connected to the network.

Each C-Bus network requires at least one system clock generating unit for data synchronisation.

The isolation between the mains supply circuitry and the 36V dc C-Bus circuitry is greater than 3.5kV. This is achieved using double wound transformers and opto isolators. This means the C-Bus wiring, connections and circuitry can be considered Extra Low Voltage.

C-Bus Protocol

C-Bus or Clipsal Bus is a closed protocol. The C-Bus was developed using the ISO 7 layer reference model. C-Bus supports a number of interfaces such as RS232 and TCP/IP and makes these protocols available to third party companies. Clipsal has also developed a server application called C-Gate, to facilitate software integration. The C-Bus interface specifications are available at no-cost through the C-Bus Enabled Program, however it is necessary to agree to a license agreement. It is also possible to become a C-Bus enabled partner; This requires payment but provides a greater level of support for product development and certification.

The future of C-Bus

C-Bus as a home automation and building lighting control system is used primarily in Australia (Sydney Opera House etc.). C-Bus is currently available in Asia, the United Kingdom (installed in Wembley Stadium and Manchester City Football Club), Russia, USA (named SquareD) and a number of other countries are now using this system. One major obstacle to widespread use of wired C-Bus is that it will not work with a standard mains wire installation, a completely new wiring system must be installed for a wired C-Bus system which means that it is normally only used for new builds. The C-Bus wireless (RF) system can however be retrofitted using the existing mains wiring.

C-Bus is compatible with BACnet, TCP/IP, Crestron, AMX, LonWorks, ModBus, Charmed Quark Controller and some other protocols through interfaces.

CEBus

CEBus(r), short for **Consumer Electronics Bus**, also known as **EIA-600**, is a set of electrical standards and communication protocols for electronic devices to transmit commands and data. It is suitable for devices in households and offices to use, and might be useful for utility interface and light industrial applications.

History

In 1984, members of the Electronic Industries Alliance (EIA) identified a need for standards that included more capability than the defacto home automation standard X10. X10 provided blind transmission of the commands ON, OFF, DIM, BRIGHT, ALL LIGHTS ON, and ALL UNITS OFF over powerline carrier, and later infrared and short range radio mediums. Over a six year period, engineers representing international companies met on a regular basis and developed a proposed standard. They called this standard CEBus (pronounced "see bus"). The CEBus standard was released in September 1992.

CEBus is an open architecture set of specification documents which define protocols for products to communicate through power line wire, low voltage twisted pair wire, coax, infrared, RF, and fiber optics.

The CEBus Standard was developed on the foundation of an IR (infrared) protocol developed by GE (General Electric). This work was transferred to the EIA at the beginning of the EIA's involvement, under the plan that it would be expanded then maintained by the EIA.

Technology

Powerline carrier

The CEBus standard includes such things as spread spectrum modulation on the power line. Spread spectrum involves starting a modulation at one frequency, and altering the frequency during its cycle. The CEBus power line standard begins each burst at 100 kHz, and increases linearly to 400 kHz during a 100 microsecond duration. Both the bursts (referred to as "superior" state) and the absence of burst (referred to as the "inferior" state) create similar digits, so a pause in between is not necessary.

A digit 1 is created by an inferior or superior state that lasts 100 microseconds, and a digit 0 is created by an inferior or superior state that lasts 200 microseconds. Consequently, the transmission rate is variable, depending upon how many of the characters are *one* and how many are *zero*; the average rate is about 7,500 bits per second. A 400 microsecond burst is an *end of frame* indicator and also saves time. For example, if the 32-bit destination address field has some of its most significant bits zero, they need not be sent; the *end of frame* delimits the field and all receiving devices assume the untransmitted bits are zero.

CEBus transmissions are strings or packets of data that also vary in length, depending upon how much data is included. Some packets can be hundreds of bits in length. The minimum packet size is 64 bits, which at an average rate of 7,500 bits per second, will take about 1/117th of a second to be transmitted and received.

Other media

Other media besides powerline carrier are specified: coaxial cable, infrared, radio frequency, and optical fiber. The initial offerings supported only a powerline carrier.

Addresses

The CEBus standard involves device addresses that are set in hardware at the factory, and include 4 billion possibilities. The standard also offers a defined language of many object oriented controls which include commands such as volume up, fast forward, rewind, pause, skip, and temperature up or down 1 degree.

Manufacturers

Presently, all of the communications hardware, language, and protocol is available on a chip produced by Intellon Corporation in Ocala, Florida and by Domosys Corporation in Quebec City, Quebec, Canada. Intellon or Domosys sell the chip to other manufacturers for use in their products, and offer to manufacture private label and OEM products using the CEBus standard. Intellon and Domosys also sell developer kits to develop a CEBus compatible product.

Having moved out of the laboratory and into the market, the CEBus trademark is owned by the EIA. Ongoing developments are conducted by a group known as the CIC (CEBus Industry Council). The CIC is a non-profit organization made up of the representatives of many national and international electronics firms, such as Microsoft, IBM, Compaq Computer Corp, AT&T Bell Labs, Honeywell, Panasonic, Sony, Thomson Consumer Electronics, Leviton, and Pacific Gas & Electric. Anyone can become a member of the CIC by paying an annual fee of \$300 to \$10,000 and fulfilling certain other requirements.

Although there is no restriction from anyone using the CEBus standard, the CIC is developing a non-profit testing laboratory which will be funded by certification charges. Manufacturers are encouraged to use the testing laboratory to verify the conformance of their product and its performance in a home network environment. When the performance is certified, the manufacturer pays a certification fee and is licensed to include the CEBus logo on their product.

European Home Systems Protocol

European Home Systems (EHS) Protocol was aimed at home appliances control and communication using power line communication (PLC). Developed by EHSA, European Home Systems Association. Now, after merging with two other protocols, it is a part of KNX protocol, which complies with CENELEC norm EN 50090 and has a chance to be a basis for the first open standard for home and building control.

KNX (standard)

KNX is a standardised (EN 50090, ISO/IEC 14543), OSI-based network communications protocol for intelligent buildings. KNX is the successor to, and convergence of, three previous standards: the European Home Systems Protocol (EHS), BatiBUS, and the European Installation Bus (EIB or Instabus). The KNX standard is administered by the KNX Association.

KNX protocol

The standard is based on the communication stack of EIB but enlarged with the physical layers, configuration modes and application experience of BatiBUS and EHS.

KNX defines several physical communication medias:

- Twisted pair wiring (inherited from the BatiBUS and EIB Instabus standards)
- Powerline networking (inherited from EIB and EHS - similar to that used by X10)
- Radio (KNX-RF)
- Infrared
- Ethernet (also known as EIBnet/IP or KNXnet/IP)

KNX is designed to be independent of any particular hardware platform. A KNX Device Network can be controlled by anything from an 8-bit microcontroller to a PC, according to the needs of a particular implementation. The most common form of installation is over twisted pair medium.

KNX is approved as an open standard to:

- International standard (ISO/IEC 14543-3)
- Canadian standard (CSA-ISO/IEC 14543-3)
- European Standard (CENELEC EN 50090 and CEN EN 13321-1)
- China Guo Biao (GB/Z 20965)

KNX Association, as of June 2010, has over 200 members/manufacturers including:

- Berker GmbH Co. KG
- ABB
- AMX
- Cisco
- Control4 EMEA
- Jung
- Miele & Cie KG
- ON Semiconductor
- Hager
- Schneider Electric Industries S.A.

- Uponor corporation
- Bosch
- Russound/FMP Inc.
- Siemens
- Toshiba

The complete list can be found here at knx.org

These companies have almost 7000 KNX certified product groups in their catalogues. The KNX Association has partnership agreements with more than 30,000 installer companies in 100 countries and more than 60 technical universities as well as over 150 training centres.

Wire transmission

Twisted pair using differential signaling with a signaling speed of 9600 bit/s. Ideal wave resistance at 100 kHz is 120 Ω . Line resistance at 20 Ω /km, max 75 Ω /km. Maximum capacitance bus-to-bus line max 800 pF/m at 800 Hz. Higher capacitance requires proportionally shorter cable length. Bus power with 30 V DC and 25 mA. Devices are addressed with 8-bits.

Configuration modes

There are three categories of KNX device:

- **A-mode** or "Automatic mode" devices automatically configure themselves, and are intended to be sold to and installed by the end user.
- **E-mode** or "Easy mode" devices require basic training to install. Their behaviour is pre-programmed, but has configuration parameters that need to be tailored to the user's requirements.
- **S-mode** or "System mode" devices are used in the creation of bespoke building automation systems. S-mode devices have no default behaviour, and must be programmed and installed by specialist technicians.

LonWorks

LonWorks is a networking platform specifically created to address the needs of control applications. 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. It is used for the automation of various functions within buildings such as lighting and HVAC.

Origins and uptake

The technology has its origins with chip designs, power line and twisted pair, signaling technology, routers, network management software, and other products from Echelon Corporation. In 1999 the communications protocol (then known as LonTalk) was submitted to ANSI and accepted as a standard for control networking (**ANSI/CEA-709.1-B**). Echelon's power line and twisted pair signaling technology was also submitted to ANSI for standardization and accepted. Since then, ANSI/CEA-709.1 has been accepted as the basis for IEEE 1473-L (in-train controls), AAR electro-pneumatic braking systems for freight trains, IFSF (European petrol station control), SEMI (semiconductor equipment manufacturing), and in 2005 as EN 14908 (European building automation standard). The protocol is also one of several data link/physical layers of the BACnet ASHRAE/ANSI standard for building automation.

China ratified the technology as a national controls standard, GB/Z 20177.1-2006 and as a building and intelligent community standard, GB/T 20299.4-2006; and in 2007 CECED, the European Committee of Domestic Equipment Manufacturers, adopted the protocol as part of its Household Appliances Control and Monitoring – Application Interworking Specification (AIS) standards.

During 2008 ISO and IEC have granted the communications protocol, twisted pair signaling technology, power line signaling technology, and Internet Protocol (IP) compatibility standard numbers ISO/IEC 14908-1, -2, -3, and -4.

Usage

By 2010 approximately 90 million devices were installed with LonWorks technology. Manufacturers in a variety of industries including building, home, street lighting, transportation, utility, and industrial automation have adopted the platform as the basis for their product and service offerings. Statistics as to the number of locations using the LonWorks technology are scarce, but it is known that products and applications built on top of the platform include such diverse functions as embedded machine control, municipal and highway/tunnel/street lighting, heating and air conditioning systems, intelligent electricity metering, subway train control, stadium lighting and speaker control, security systems, fire detection and suppression, and newborn location monitoring and alarming.

Technical details

Two physical-layer signaling technologies, twisted pair "free topology" and power line carrier, are typically included in each of the standards created around the LonWorks technology. The two-wire layer operates at 78 kbit/s using differential Manchester encoding, while the power line achieves either 5.4 or 3.6 kbit/s, depending on frequency.

Additionally, the LonWorks platform uses an affiliated IP tunneling standard—ISO/IEC 14908-4 (ANSI/CEA-852) -- in use by a number of manufacturers to connect the devices on previously deployed and new LonWorks platform-based networks to IP-aware applications or remote network-management tools. Many LonWorks platform-based control applications are being implemented with some sort of IP integration, either at the UI/application level or in the controls infrastructure. This is accomplished with web services or IP-routing products available on the market.

An Echelon Corporation-designed IC consisting of several 8-bit processors, the "Neuron chip" was initially the only way to implement a LonTalk protocol node and is used in the large majority of LonWorks platform-based hardware. Since 1999, the protocol has been available for general-purpose processors: a port of the ANSI/CEA-709.1 standard to IP-based or 32-bit chips.

Applications using LonWorks

- Semiconductor manufacturing
- Lighting control systems
- Energy management systems
- Heating/ventilation/air-conditioning systems
- Security systems
- Home automation
- Consumer appliance controls
- Public street lighting, monitoring, and control
- Petrol station control
- Rail Electronically Controlled Pneumatic Braking

SNVTs (Standard Network Variable Types)

One of the keys to the interoperability of the system is the standardisation of the variables used to describe physical things to LonWorks, this standards list is maintained by LonMark International and each standard is known as Standard Network Variable Types (SNVTs, pronounced "sniv-its") so for example a thermostat using the temperature SNVT is expected to produce a number between zero and 65535 that equates to a temperature between -274 and 6279.5 degrees Celsius.

X10 (industry standard)



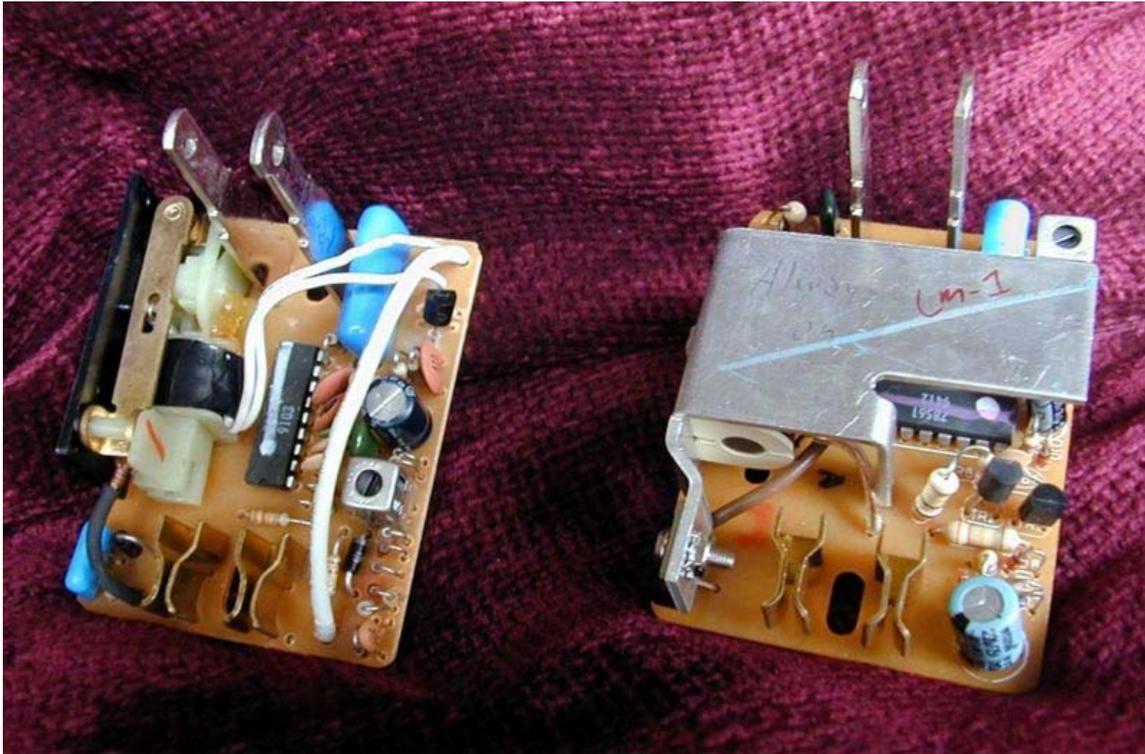
X10 modules (clockwise from upper left): An original BSR lamp module, a "chime module", a recent lamp module, an outlet module

X10 is an international and open industry standard for communication among electronic devices used for home automation, also known as *domotics*. It primarily uses power line wiring for signaling and control, where the signals involve brief radio frequency bursts representing digital information. A wireless radio based protocol transport is also defined.

X10 was developed in 1975 by Pico Electronics of Glenrothes, Scotland, in order to allow remote control of home devices and appliances. It was the first general purpose domotic network technology and remains the most widely available.

Although a number of higher bandwidth alternatives exist, X10 remains popular in the home environment with millions of units in use worldwide, and inexpensive availability of new components.

Power line carrier control overview



X10 modules: The interior of an appliance module (note the impulse relay on the left) and a lamp module (note the TRIAC and heat sink)

Household electrical wiring (the same which powers lights and appliances) is used to send digital data between X10 devices. This digital data is encoded onto a 120 kHz carrier which is transmitted as bursts during the relatively quiet zero crossings of the 50 or 60 Hz AC alternating current waveform. One bit is transmitted at each zero crossing.

The digital data consists of an address and a command sent from a controller to a controlled device. More advanced controllers can also query equally advanced devices to respond with their status. This status may be as simple as "off" or "on", or the current dimming level, or even the temperature or other sensor reading. Devices usually plug into the wall where a lamp, television, or other household appliance plugs in; however some built-in controllers are also available for wall switches and ceiling fixtures.

The relatively high-frequency carrier frequency carrying the signal cannot pass through a power transformer or across the phases of a multiphase system. For split phase systems, the signal can be passively coupled from phase-to-phase using a passive capacitor, but for three phase systems or where the capacitor provides insufficient coupling, an active X10 repeater can be used. To allow signals be coupled across phases and still match each phase's zero crossing point, each bit is transmitted three times in each half cycle, offset by 1/6th cycle.

It may also be desirable to block X10 signals from leaving the local area so, for example, the X10 controls in one house do not interfere with the X10 controls in a neighboring house. In this situation, inductive filters can be used to attenuate the X10 signals coming into or going out of the local area.

X10 protocol

Whether using power line or radio communications, packets transmitted using the X10 control protocol consist of a four bit *house code* followed by one or more four bit *unit code*, finally followed by a four bit command. For the convenience of users configuring a system, the four bit house code is selected as a letter from A through P while the four bit unit code is a number 1 through 16.

When the system is installed, each controlled device is configured to respond to one of the 256 possible addresses (16 house codes × 16 unit codes); each device reacts to commands specifically addressed to it, or possibly to several broadcast commands.

The protocol may transmit a message that says "select code A3", followed by "turn on", which commands unit "A3" to turn on its device. Several units can be addressed before giving the command, allowing a command to affect several units simultaneously. For example, "select A3", "select A15", "select A4", and finally, "turn on", causes units A3, A4, and A15 to all turn on.

Note that there is no restriction (except possibly consideration of the neighbors) that prevents using more than one house code within a single house. The "all lights on" command and "all units off" commands will only affect a single house code, so an installation using multiple house codes effectively has the devices divided into separate zones.

List of X10 commands:

Code	Function	Description
0 0 0 0	All units off	Switch off all devices with the house code indicated in the message
0 0 0 1	All lights on	Switches on all lighting devices (with the ability to control brightness)
0 0 1 0	On	Switches on a device
0 0 1 1	Off	Switches off a device
0 1 0 0	Dim	Reduces the light intensity

0 1 0 1	Bright	Increases the light intensity
0 1 1 1	Extended code	Extension code
1 0 0 0	Hail request	Requests a response from the device(s) with the house code indicated in the message
1 0 0 1	Hail acknowledge	Response to the previous command
1 0 1 x	Pre-set dim	Allows the selection of two predefined levels of light intensity
1 1 0 1	Status is on	Response to the Status Request indicating that the device is switched on
1 1 1 0	Status is off	Response indicating that the device is switched off
1 1 1 1	Status request	Request requiring the status of a device

Power line protocol physical layer details

In the 60 Hz AC current flow, a bit value of one is represented by a 1 millisecond burst of 120 kHz at the zero crossing point (nominally 0°, but within 200 microseconds of the zero crossing point), immediately followed by the absence of a pulse. A zero value is represented by the absence of 120 kHz at the zero crossing point (pulse), immediately followed by the presence of a pulse. All messages are sent twice to reduce false signaling. After allowing for retransmission, line control, etc., data rates are around 20 bit/s, making X10 data transmission so slow that the technology is confined to turning devices on and off or other very simple operations.

In order to provide a predictable start point, every data frame transmitted always begin with a *start code* of 1110. Immediately after the start code, a *house code* (A–P) appears, and after the letter code comes a *function code*. Function codes may specify a unit number code (1–16) or a command code, the selection between the two modes being determined by the last bit where 0=unit number and 1=command. One start code, one letter code, and one function code is known as an X10 **frame** and represent the minimum components of a valid X10 data packet.

Each frame is sent twice in succession to make sure the receivers understand it over any power line noise for purposes of redundancy, reliability, and to accommodate line repeaters.

Whenever the data changes from one address to another address, from an address to a command, or from one command to another command, the data frames must be separated

by at least 6 clear zero crossings (or "000000"). The sequence of six zeros resets the device decoder hardware.

The radio protocol



A four-channel radio switch and radio-to-power-line transponder

To allow the operation of wireless keypads, remote switches, and the like, a radio protocol is also defined. Operating at a frequency of 310 MHz in the U.S. and 433 MHz in European systems, the wireless devices send data packets that are very similar to ordinary X10 power line control packets. A radio receiver then provides a bridge which translates these radio packets to ordinary X10 power line control packets.

The devices available using the radio protocol include:

- Keypad controllers ("clickers")
- Keychain controllers that can control one to four X10 devices
- Burglar alarm modules that can transmit sensor data
- Passive infrared switches to control lighting and X-10 chimes
- Non-passive information bursts

Device modules



X10 modules: A lamp socket module

Depending on the load that is to be controlled, different modules must be used. For incandescent lamp loads, a *lamp module* or *wall switch* module can be used. These modules switch the power using a TRIAC solid state switch and are also capable of dimming the lamp load. Lamp modules are almost silent in operation, and generally rated to control loads ranging from approximately 40 to 500 watts.

For loads other than incandescent lamps, such as fluorescent lamps, high-intensity discharge lamps, and electrical home appliances, the triac-based electronic switching in the lamp module is unsuitable and an *appliance module* must be used instead. These modules switch the power using an impulse relay. In the U.S., these modules are generally rated to control loads up to 15 amperes (1800 watts at 120V).

Many device modules offer a feature called *local control*. If the module is switched off, operating the power switch on the lamp or appliance will cause the module to turn on. In this way, a lamp can still be lit or a coffee pot turned on without the need to use an X10 controller. Wall switch modules may not offer this feature.

Some wall switch modules offer a feature called *local dimming*. Ordinarily, the local push button of a wall switch module simply offers on/off control with no possibility of locally dimming the controlled lamp. If local dimming is offered, holding down the push button will cause the lamp to cycle through its brightness range.

Higher end modules have more advanced features such as programmable on levels, customizable fade rates, the ability to transmit commands when used (referred to as 2-way devices), and *scene* support.

There are sensor modules that sense and report temperature, light, infra-red, motion, or contact openings and closures. Device modules include thermostats, audible alarms and controllers for low voltage switches.

Controllers



X10 controllers: A simple controller, a radio controller, and an original controller usable with an ultrasonic remote control

X10 controllers range from extremely simple to very sophisticated.

The simplest controllers are arranged to control four X10 devices at four sequential addresses (1–4 or 5–8). The controllers typically contain the following buttons:

- Unit 1 on/off
- Unit 2 on/off
- Unit 3 on/off
- Unit 4 on/off
- Brighten/dim (last selected unit)
- All lights on/all units off

More sophisticated controllers can control more units and/or incorporate timers that perform preprogrammed functions at specific times each day. Units are also available that use passive infrared motion detectors or photocells to turn lights on and off based on external conditions.

Finally, very sophisticated units are available that can be fully programmed or, like the X10 Firecracker, use a program running in an external computer. These systems can execute many different timed events, respond to external sensors, and execute, with the press of a single button, an entire *scene*, turning lights on, establishing brightness levels, and so on. Control programs are available for computers running Microsoft Windows, Apple's Macintosh, Linux and FreeBSD operating systems.

Burglar alarm systems are also available. These systems contain door/window sensors as well as motion sensors that use a coded RF signal to identify when they are tripped or just to routinely check-in and give a heart-beat signal to show that the system is still active. Users can arm and disarm their system via several different remote controls which also use a coded RF signal to ensure security. When an alarm is triggered the console will make an outbound phone call with a recorded message. The console will also use X10 protocols to flash lights when an alarm has been triggered while the security console sounds an external siren. Using X10 protocols signals will also be sent to remote sirens for additional security.

Weak points and limitations

Compatibility with installed wiring and appliances

One problem with X10 is excessive attenuation of signals between the two live conductors in the 3-wire 120/240 volt system used in typical North American residential construction. Signals from a transmitter on one live conductor may not propagate through the high impedance of the distribution transformer winding to the other live conductor. Often, there's simply no reliable path to allow the X10 signals to propagate from one transformer leg wire to the other; this failure may come and go as large 240 volt devices such as stoves or dryers are turned on and off. (When turned on, such devices provide a low-impedance bridge for the X10 signals between the two leg wires.) This problem can be permanently overcome by installing a capacitor between the leg wires as a path for the X10 signals; manufacturers commonly sell signal couplers that plug into 240 volt sockets

that perform this function. More sophisticated installations install an active repeater device between the legs, while others combine signal amplifiers with a coupling device. A repeater is also needed for inter-phase communication in homes with three-phase electric power. In many countries outside North America, entire houses are typically wired from a single 240 volt single-phase wire, so this problem does not occur.

An RCD/GFCI can attenuate X10 signals passing through the device. This means that X10 signals passing through an RCD may not be strong enough to provide reliable communication.

Television receivers or household wireless devices may cause spurious "off" or "on" signals. Noise filtering (as installed on computers as well as many modern appliances) may help keep external noise out of X10 signals, but noise filters not designed for X10 may also attenuate X10 signals traveling on the branch circuit to which the appliance is connected.

Certain types of power supplies used in modern electronic equipment, such as computers, television receivers and satellite receivers, attenuate passing X10 signals by providing a low impedance path to high frequency signals. Typically, the capacitors used on the inputs to these power supplies short the X10 signal from line to neutral, suppressing any hope of X10 control on the circuit near that device. Filters are available that will block the X10 signals from ever reaching such devices; plugging offending devices into such filters can cure mysterious X10 intermittent failures.

Some X10 controllers may not work well or at all with low power devices (below 50 watts) or devices like fluorescent bulbs that do not present resistive loads. Use of an appliance module rather than a lamp module may resolve this problem.

Commands getting lost

X10 signals can only be transmitted one command at a time, first by addressing the device to control, and then sending an operation for that device to perform. If two X10 signals are transmitted at the same time they may collide or interleave, leading to commands that either cannot be decoded or that trigger incorrect operations. The CM15A and RR501 Transceiver can avoid these signal collisions that can sometimes occur with other models.

Relatively slow

The X10 protocol is slow. It takes roughly three quarters of a second to transmit a device address and a command. While generally not noticeable when using a tabletop controller, it becomes a noticeable problem when using 2-way switches or when utilizing some sort of computerized controller. The apparent delay can be lessened somewhat by using slower device dim rates. With more advanced modules another option is to use group control (lighting scene) extended commands. These allow to adjust several modules at once by a single command.

Limited functionality

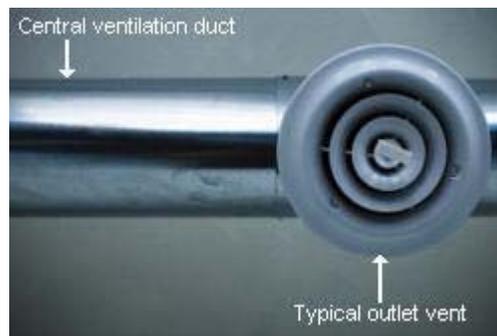
X10 protocol does support more advanced control over the dimming speed, direct dim level setting and group control (scene settings). This is done via extended message set, which is an official part of X10 standard . However support for all extended messages is not mandatory, and a lot of cheaper modules implement only the basic message set. These require adjusting each lighting circuit one after the other, which can be visually unappealing and also very slow.

Interference and lack of encryption

The standard X10 power line and RF protocols lack support for encryption, and can only address 256 devices. Unfiltered power line signals from close neighbors using the same X10 device addresses may interfere with each other. Interfering RF wireless signals may similarly be received, with it being easy for anyone nearby with an X10 RF remote to wittingly or unwittingly cause mayhem if an RF to power line device is being used on a premises.

Chapter- 5

HVAC

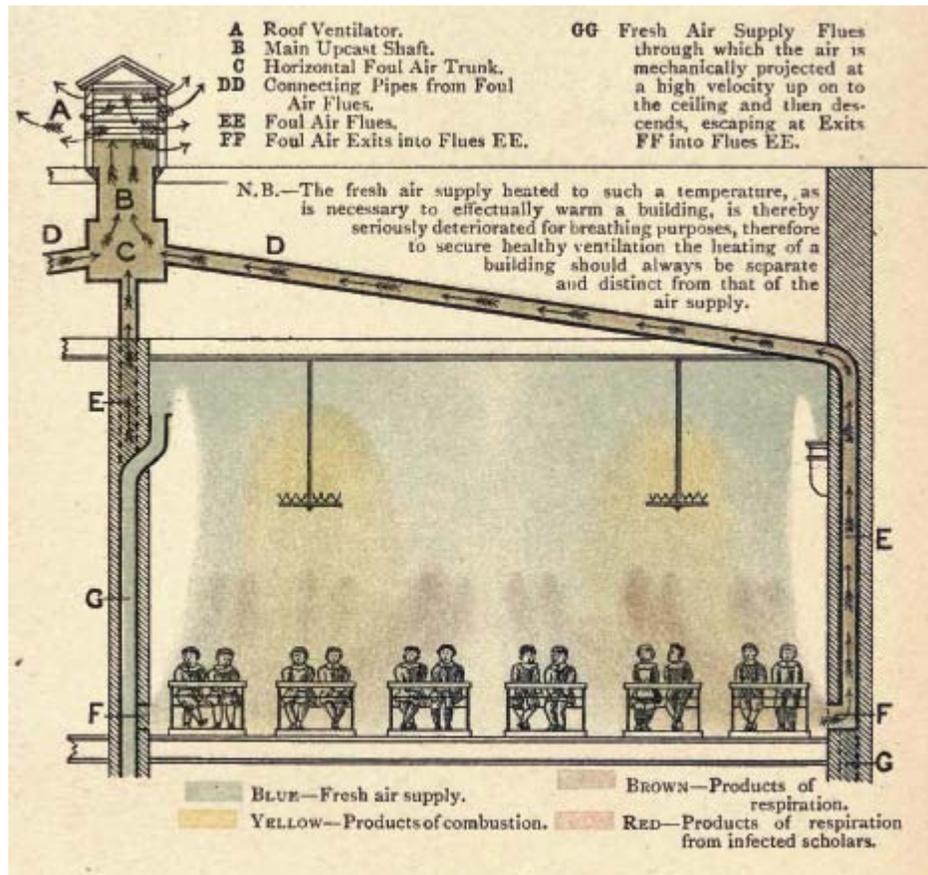


HVAC systems use ventilation air ducts installed throughout a building that supply conditioned air to a room through rectangular or round outlet vents, called diffusers; and ducts that remove air through return-air grilles

HVAC (Heating, Ventilating, and Air Conditioning) refers to technology of indoor or automotive environmental comfort. HVAC system design is a major subdiscipline of mechanical engineering, based on the principles of thermodynamics, fluid mechanics, and heat transfer. Refrigeration is sometimes added to the field's abbreviation as HVAC&R or HVACR, or ventilating is dropped as in HACR (such as the designation of HACR-rated circuit breakers).

HVAC is particularly important in the design of medium to large industrial and office buildings such as skyscrapers and in marine environments such as aquariums, where safe and healthy building conditions are regulated with temperature and humidity, as well as "fresh air" from outdoors.

Background



Ventilation (architecture) on the draught system, by impulsion, or the 'plenum' principle, applied to schoolrooms (1899)

Heating, ventilating, and air conditioning is based on inventions and discoveries made by Nikolay Lvov, Michael Faraday, Willis Carrier, Reuben Trane, James Joule, William Rankine, Sadi Carnot, and many others.

The invention of the components of HVAC systems went hand-in-hand with the industrial revolution, and new methods of modernization, higher efficiency, and system control are constantly introduced by companies and inventors all over the world. The three central functions of heating, ventilating, and air-conditioning are interrelated, providing thermal comfort, acceptable indoor air quality, within reasonable installation, operation, and maintenance costs. HVAC systems can provide ventilation, reduce air infiltration, and maintain pressure relationships between spaces. How air is delivered to, and removed from spaces is known as room air distribution.

In modern buildings the design, installation, and control systems of these functions are integrated into one or more HVAC systems. For very small buildings, contractors normally "size" and select HVAC systems and equipment. For larger buildings, building

services designers and engineers, such as mechanical, architectural, or building services engineers analyze, design, and specify the HVAC systems, and specialty mechanical contractors build and commission them. Building permits and code-compliance inspections of the installations are normally required for all sizes of buildings.

The HVAC industry is a worldwide enterprise, with career opportunities including operation and maintenance, system design and construction, equipment manufacturing and sales, and in education and research. The HVAC industry had been historically regulated by the manufacturers of HVAC equipment, but Regulating and Standards organizations such as HARDI, ASHRAE, SMACNA, ACCA, Uniform Mechanical Code, International Mechanical Code, and AMCA have been established to support the industry and encourage high standards and achievement.

Design of the HVAC system.

The starting point in carrying out a heat estimate both for cooling and heating will depends on the ambient and inside conditions specified. However before taking up the heat load calculation, it is necessary to work out the fresh air requirement for each area in details, as pressurization is an important requirement.

Heating



Central heating unit

There are many different types of standard heating systems. Central heating is often used in cold climates to heat private houses and public buildings. Such a system contains a boiler, furnace, or heat pump to heat water, steam, or air, all in a central location such as a furnace room in a home or a mechanical room in a large building. The use of water as the heat transfer medium is known as hydronics. The system also contains either ductwork, for forced air systems, or piping to distribute a heated fluid and radiators to transfer this heat to the air. The term *radiator* in this context is misleading since most

heat transfer from the heat exchanger is by convection, not radiation. The radiators may be mounted on walls or buried in the floor to give under-floor heat.

In boiler fed or radiant heating systems, all but the simplest systems have a pump to circulate the water and ensure an equal supply of heat to all the radiators. The heated water can also be fed through another (secondary) heat exchanger inside a storage cylinder to provide hot running water.

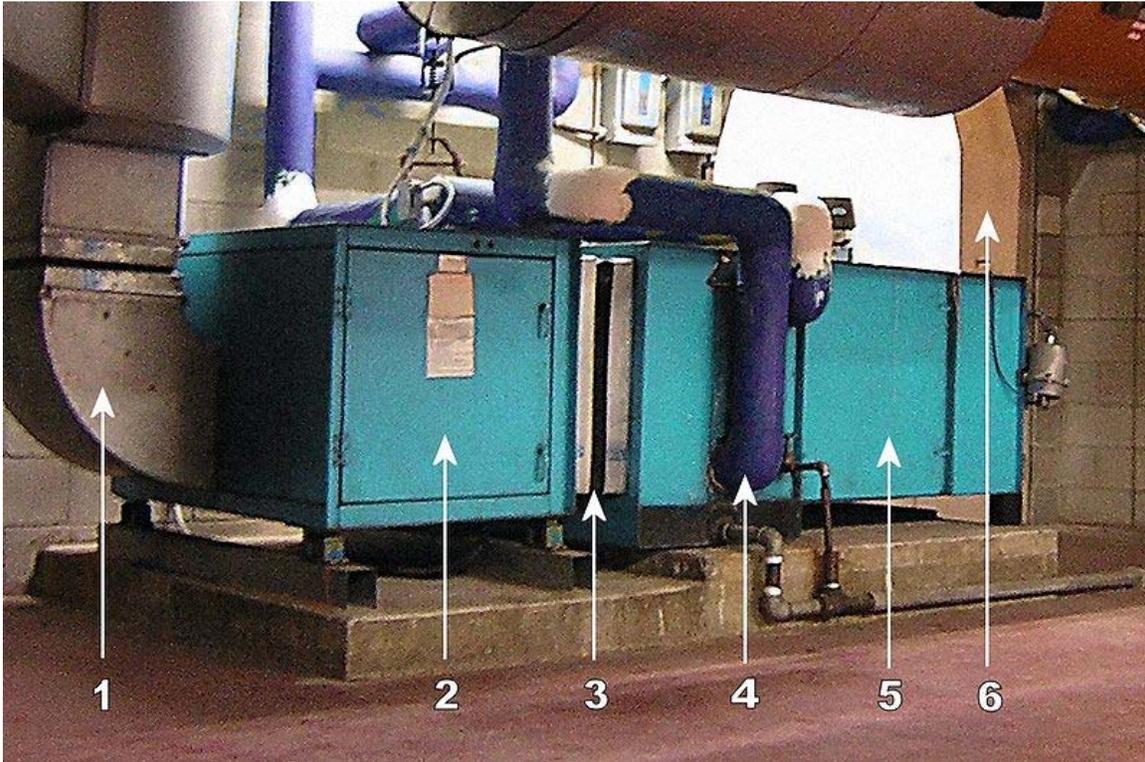
Forced air systems send heated air through ductwork. During warm weather the same ductwork can be used for air conditioning. The forced air can also be filtered or put through air cleaners.

Heating can also be provided from electric, or resistance heating using a filament that becomes hot when electric current is caused to pass through it. This type of heat can be found in electric baseboard heaters, portable electric heaters, and as backup or supplemental heating for heat pump (or reverse heating) system.

The heating elements (radiators or vents) should be located in the coldest part of the room, typically next to the windows to minimize condensation and offset the convective air current formed in the room due to the air next to the window becoming negatively buoyant due to the cold glass. Devices that direct vents away from windows to prevent "wasted" heat defeat this design intent. Cold air drafts can contribute significantly to subjectively feeling colder than the average room temperature. Therefore, it is important to control the air leaks from outside in addition to proper design of the heating system.

The invention of central heating is often credited to the ancient Romans, who installed a system of air ducts called a hypocaust in the walls and floors of public baths and private villas.

Ventilating



An air handling unit is used for the heating and cooling of air in a central location.

Ventilating is the process of "changing" or replacing air in any space to control temperature or remove moisture, odors, smoke, heat, dust, airborne bacteria, carbon dioxide, and to replenish oxygen. Ventilation includes both the exchange of air to the outside as well as circulation of air within the building. It is one of the most important factors for maintaining acceptable indoor air quality in buildings. Methods for ventilating a building may be divided into *mechanical/forced* and *natural* types. Ventilation is used to remove unpleasant smells and excessive moisture, introduce outside air, to keep interior building air circulating, and to prevent stagnation of the interior air.

Mechanical or forced ventilation

"Mechanical" or "forced" ventilation is used to control indoor air quality. Excess humidity, odors, and contaminants can often be controlled via dilution or replacement with outside air. However, in humid climates much energy is required to remove excess moisture from ventilation air.

Kitchens and bathrooms typically have mechanical exhaust to control odors and sometimes humidity. Factors in the design of such systems include the flow rate (which is a function of the fan speed and exhaust vent size) and noise level. If ducting for the fans traverse unheated space (e.g., an attic), the ducting should be insulated as well to prevent

condensation on the ducting. Direct drive fans are available for many applications, and can reduce maintenance needs.

Ceiling fans and table/floor fans circulate air within a room for the purpose of reducing the perceived temperature because of evaporation of perspiration on the skin of the occupants. Because hot air rises, ceiling fans may be used to keep a room warmer in the winter by circulating the warm stratified air from the ceiling to the floor. Ceiling fans do not provide ventilation as defined as the introduction of outside air.

Natural ventilation

Natural ventilation is the ventilation of a building with outside air without the use of a fan or other mechanical system. It can be achieved with openable windows or trickle vents when the spaces to ventilate are small and the architecture permits. In more complex systems warm air in the building can be allowed to rise and flow out upper openings to the outside (stack effect) thus forcing cool outside air to be drawn into the building naturally through openings in the lower areas. These systems use very little energy but care must be taken to ensure the occupants' comfort. In warm or humid months, in many climates, maintaining thermal comfort solely via natural ventilation may not be possible so conventional air conditioning systems are used as backups. Air-side economizers perform the same function as natural ventilation, but use mechanical systems' fans, ducts, dampers, and control systems to introduce and distribute cool outdoor air when appropriate.

Air conditioning

Air conditioning and refrigeration are provided through the removal of heat. The definition of cold is the absence of heat and all air conditioning systems work on this basic principle. Heat can be removed through the process of radiation, convection, and Heat cooling through a process called the refrigeration cycle. The conduction mediums such as water, air, ice, and chemicals are referred to as refrigerants.

An air conditioning system, or a standalone air conditioner, provides cooling, ventilation, and humidity control for all or part of a house or building.

The refrigerant cycle consists of four essential elements to create a cooling effect. The system refrigerant starts its cycle in a gaseous state. The compressor pumps the refrigerant gas up to a high pressure and temperature. From there it enters a heat exchanger (sometimes called a "condensing coil") where it loses energy (heat) to the outside. In the process the refrigerant condenses into a liquid. The liquid refrigerant is returned indoors to another heat exchanger ("evaporating coil"). A metering device allows the liquid to flow in at a low pressure at the proper rate. As the liquid refrigerant evaporates it absorbs energy (heat) from the inside air, returns to the compressor, and the cycle repeats. In the process, heat is absorbed from indoors, and transferred outdoors, resulting in cooling of the building.

Central, 'all-air' air conditioning systems are often installed in modern residences, offices, and public buildings, but are difficult to retrofit (install in a building that was not designed to receive it) because of the bulky air ducts required. A duct system must be carefully maintained to prevent the growth of pathogenic bacteria in the ducts. An alternative to large ducts to carry the needed air to heat or cool an area is the use of remote fan coils or split systems. These systems, although most often seen in residential applications, are gaining popularity in small commercial buildings. The evaporator coil is connected to a remote condenser unit using piping instead of ducts.

Dehumidification in an air conditioning system is provided by the evaporator. Since the evaporator operates at a temperature below dew point, moisture in the air condenses on the evaporator coil tubes. This moisture is collected at the bottom of the evaporator in a condensate pan and is removed by piping it to a central drain or onto the ground outside. A dehumidifier is an air-conditioner-like device that controls the humidity of a room or building. It is often employed in basements which have a higher relative humidity because of their lower temperature (and propensity for damp floors and walls). In food retailing establishments, large open chiller cabinets are highly effective at dehumidifying the internal air. Conversely, a humidifier increases the humidity of a building.

Air-conditioned buildings often have sealed windows, because open windows would disrupt the attempts of the HVAC system to maintain constant indoor air conditions.

All modern air conditioning systems, down to small "window" units, are equipped with internal air filters. These are generally of a light weight gauze-type element, and must be replaced as conditions warrant (some models may be washable). For example, a building in a high-dust environment, or a home with furry pets, will need to have the filters changed more often than buildings without these dirt loads. Failure to replace these filters as needed will contribute to a lower heat-exchange rate, resulting in wasted energy, shortened equipment life, and higher energy bills; also low air flow can result in "iced-up" or "iced-over" evaporator coils, and then there is no air flow at all. Additionally, very dirty or plugged filters can cause overheating during a heating cycle, and can possibly result in damage to the furnace unit or even fire.

It is important to keep in mind that because an air conditioner moves heat from the indoor (evaporator) coil to the outdoor (condenser) coil, the latter must be kept just as clean as the former. This means that, in addition to replacing the air filter at the evaporator coil, it is also necessary to regularly clean the condenser coil. Failure to keep the condenser clean will eventually result in harm to the compressor, because the condenser coil is responsible for discharging both the indoor heat (as picked up by the evaporator) plus the heat generated by the electric motor driving the compressor.

Outside, "fresh" air is generally drawn into the system by a vent into the evaporator section. Adjustment of the percentage of return air made up of fresh air can usually be adjusted by manipulating the opening of this vent.

Energy efficiency

For the last 20 to 30 years, manufacturers of HVAC equipment have been making an effort to make the systems they manufacture more efficient. This was originally driven by rising energy costs, and has more recently been driven by increased awareness of environmental issues. In the USA, the EPA has also imposed tighter restrictions. There are several methods for making HVAC systems more efficient.

Heating energy

Water heating is more efficient for heating buildings and was the standard many years ago. Today forced air systems can double for air conditioning and are more popular.

A couple of benefits of forced air systems, which are now widely applied in churches, schools and high-end residences, are 1) better air conditioned effect 2) up to 15-20% energy saving, and 3) evenly conditioned effect. A drawback is the installation cost, which might be slightly higher than traditional HVAC system.

Energy efficiency can be improved even more in central heating systems by introducing zoned heating. This allows a more granular application of heat, similar to non-central heating systems. Zones are controlled by multiple thermostats. In water heating systems the thermostats control zone valves, and in forced air systems they control zone dampers inside the vents which selectively block the flow of air. In this case, the control system is very critical to maintain a proper temperature.

Geothermal Heat Pump

Geothermal heat pumps are similar to ordinary heat pumps, but instead of using heat found in outside air, they rely on the stable, even heat of the earth to provide heating, air conditioning and, in most cases, hot water. From Montana's -70°F (-57°C) temperature, to the highest temperature ever recorded in the U.S.— 134°F (56.7°C) in Death Valley, California, in 1913—many parts of the country experience seasonal temperature extremes. A few feet below the earth's surface, however, the ground remains at a relatively constant temperature. Although the temperatures vary according to latitude, at 6 feet (1.83 m) underground, temperatures range from 45 to 75°F (7.2 to 23.9°C).

While they may be more costly to install initially than regular heat pumps, they can produce markedly lower energy bills—30 percent to 40 percent lower, according to estimates from the U.S. Environmental Protection Agency.

Ventilation Energy recovery

Energy recovery systems sometimes utilize heat recovery ventilation or energy recovery ventilation systems that employ heat exchangers or enthalpy wheels to recover sensible or

latent heat from exhausted air. This is done by transfer of energy to the incoming outside fresh air.

Air conditioning energy

The performance of vapor compression refrigeration cycles is limited by thermodynamics. These air conditioning and heat pump devices *move* heat rather than convert it from one form to another, so *thermal efficiencies* do not appropriately describe the performance of these devices. The **Coefficient-of-Performance (COP)** measures performance, but this dimensionless measure has not been adopted, but rather the **Energy Efficiency Ratio (EER)**. EER is the Energy Efficiency Ratio based on a 35 °C (95 °F) outdoor temperature. To more accurately describe the performance of air conditioning equipment over a typical cooling season a modified version of the EER is used, and is the **Seasonal Energy Efficiency Ratio (SEER)**. SEER ratings are based on seasonal temperature averages instead of a constant 35 °C outdoor temperature. The current industry minimum SEER rating is 13 SEER. The SEER article describes it further, and presents some economic comparisons using this useful performance measure.

Engineers have pointed out some areas where efficiency of the existing hardware could be improved. For example, the fan blades used to move the air are usually stamped from sheet metal, an economical method of manufacture, but as a result they are not aerodynamically efficient. A well-designed blade could reduce electrical power required to move the air by a third.

- Chilled beam
- Circulator pump
- Cooling tower
- Damper (flow)
- Diffuser
- Duct
- Economizer
- Evaporative cooler
- Fan coil unit
- Fan (mechanical)
- Heater
- Heat exchanger, including 'coils'
- Heat Pump
- Heat recovery ventilator
- Humidifier / Dehumidifier
- HVAC control system
- Piping
- Valve
- Variable air volume
- Variable-frequency drive, for fine control of pumps

HVAC industry and standards

North America

USA

In the United States, HVAC engineers generally are members of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). ASHRAE is an

international technical society for all individuals and organizations interested in HVAC. The Society, organized into Regions, Chapters, and Student Branches, allows exchange of HVAC knowledge and experiences for the benefit of the field's practitioners and the public. ASHRAE provides many opportunities to participate in the development of new knowledge via, for example, research and its many Technical Committees. These committees meet typically twice per year at the ASHRAE Annual and Winter Meetings. A popular product show, the AHR Expo, is held in conjunction with each Winter Meeting. The Society has approximately 50,000 members and has headquarters at Atlanta, Georgia, USA.

American design standards are legislated in the Uniform Mechanical Code or International Mechanical Code. In certain states, counties, or cities, either of these codes may be adopted and amended via various legislative processes. These codes are updated and published by the International Association of Plumbing and Mechanical Officials (IAPMO) or the International Code Council (ICC) respectively, on a 3-year code development cycle. Typically, local Building Permit Departments are charged with enforcement of these standards on private and certain public properties.

In the United States, as well as throughout the world, HVAC contractors and companies are members of NADCA, the National Air Duct Cleaners Association. NADCA was formed in 1989 as a non-profit association of companies engaged in the cleaning of HVAC systems. Its mission was to promote source removal as the only acceptable method of cleaning and to establish industry standards for the association. NADCA has expanded its mission to include the representation of qualified companies engaged in the assessment, cleaning, and restoration of HVAC systems, and to assist its members in providing high quality service to their customers. The goal of the association is to be the number one source for the HVAC cleaning and restoration services: first time, every time. NADCA has experienced phenomenal membership growth and has been extremely successful with the training and certification of air systems cleaning specialists, mold remediators, and HVAC inspectors. The association has also published important standards and guidelines, educational materials, and other useful information for the consumer and members of NADCA. Their headquarters are located in Washington, D.C.

Europe

United Kingdom

The Chartered Institute of Building Services Engineers is a body that covers the essential Service (systems architecture) that allow buildings to operate. It includes the electrotechnical, heating, ventilating, air conditioning, refrigeration and plumbing industries. To train as a building services engineer, the academic requirement is GCSEs (A-C) / Standard Grades (1-3) in Maths and Science, which are important in measurements, planning and theory. Employers will often want a degree in a branch of engineering, such as building environment engineering, electrical engineering or mechanical engineering.

Within the construction sector, it is the job of the building services engineer to design and oversee the installation and maintenance of the essential services such as gas, electricity, water, heating and lighting, as well as many others. These all help to make buildings comfortable and healthy places to live and work in. Building Services is part of a sector that has over 51,000 businesses and employs over 500,000 people. This sector has an annual turnover of £19.3 billion which represents 2%-3% of the GDP.

The most recognized standards for HVAC design is based on ASHRAE data. ASHRAE is the American Society of Heating, Refrigerating and Air-Conditioning Engineers. The ASHRAE Handbook's most general volume, of four, is Fundamentals; it includes heating and cooling calculations. Each volume of the ASHRAE Handbook is updated every four years. The design professional must consult ASHRAE data for the standards of design and care as the typical building codes provides little to no information on HVAC design practices; such codes, such as the UMC and IMC, do include much details on installation requirements, however. Other useful reference materials include items from SMACNA, ACCA, and technical trade journals.

Australia

Air Conditioning and Mechanical Contractors Association of Australia (AMCA)
Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH)

Asia

India

The Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE) was established to promote the HVAC industry in India. ISHRAE is an associate of ASHRAE. ISHRAE was started at Delhi in 1981 and a chapter was started in Bangalore in 1989. Between 1989 & 1993, ISHRAE chapters were formed in all major cities in India and also in the Middle East.

Pakistan

Air-conditioning technology has been in use in Pakistan since 1947, the time of its independence. At that point local expertise was dependent on the supply and installation of imported equipment in accordance with the system designs from abroad. Once Pakistani engineers recognized the importance of the field they became active in developing expertise in design, manufacture, installation, operation, and maintenance. In 1995 the Pakistan HVACR Society was formed. Since then, the Society started organizing various disciplines of the field under its umbrella.

Chapter- 6

Home Automation for the Elderly and Disabled

The form of home automation called **assistive domotics** focuses on making it possible for the elderly and disabled to remain at home, safe and comfortable. Home automation is becoming a viable option for the elderly and disabled who would prefer to stay in the comfort of their homes rather than move to a healthcare facility. This field uses much of the same technology and equipment as home automation for security, entertainment, and energy conservation but tailors it towards the elderly and disabled.

Concept

While talking about technology, Microsoft Corporation's C.E.O. Steve Ballmer once said, "The number one benefit of technology is that it empowers people to do what they want to do. It lets people be creative. It lets people be productive. It lets people learn things they didn't think they could learn before, and so in a sense it is all about potential" (BrainyQuote 2007). Similarly, through new technology, a little creativity, and a lot of thinking, we have begun to produce home automation systems that make it possible for the elderly and disabled to live by themselves and meet their potential. Due to the aging population of the United States, measures must be taken in order to provide health care to the elderly. The US Census Bureau has projected that by 2010 13% of the population will be 65 or older (Cheek 2005). The bureau has also projected that by 2030 there will be 9 million Americans older than 85 (Cheek 2005). The aging population has generated a significant interest by the government, as well as industry leaders, to develop home automation systems for the elderly. Due to the drastic increases in health-care facility costs, more and more elderly people are turning to home automation, a concept also known as "smart homes", to allow them to age in the comfort of their own homes. These systems make normal Activities of Daily Living (ADL) possible for the elderly and disabled who would otherwise not be able to live on their own. Smart homes can most easily be described as "a collective term for information and communication technology in homes where components communicate through a local network" (Cheek 2005).

There are two basic forms of home automation systems for the elderly: *embedded health systems* and *private health networks*. Embedded health systems integrate sensors and microprocessors in appliances, furniture, and clothing which collect data that is analyzed and can be used to diagnose diseases and recognize risk patterns. Private health networks implement wireless technology to connect portable devices and store data in a household health database. Due to the need for more healthcare options for the aging population “there is a significant interest from industry and policy makers in developing these technologies” (Eriksson 2002).

Advantages

Home automation is being implemented into more and more homes of the elderly and disabled in order to maintain their independence and safety. These smart homes allow the elderly and disabled to stay in their homes where they feel comfortable, instead of moving to a costly health care facility. The transition to a health care facility can cause a lot of anxiety and home automation can either prevent or delay this anxiety (Cheek 2005). For the disabled smart homes give them opportunity for independence, which will help them gain confidence and determination. Smart homes can provide both the elderly and disabled with many different types of emergency assistance systems, security features, fall prevention, automated timers, and alerts. These systems allow for the individual to feel secure in their homes knowing that help is only minutes away. Smart home systems will make it possible for family members to monitor their loved ones from anywhere with an internet connection.

Systems

Home automation for healthcare can range from very simple alerts to lavish computer controlled network interfaces. Some of the monitoring or safety devices that can be installed in a home include lighting and motion sensors, environmental controls, video cameras, automated timers, emergency assistance systems, and alerts.

Matilda

The University of Florida has built a 500-square-foot (46 m²) smart house that is designed assist and to provide medical care to Matilda, a life size mannequin (Ascribe 2003). The house implements devices including “a microwave that recognizes entrees and automatically determines how long to cook them” (Ascribe 2003) and devices to track the individuals location within the home. The house also uses devices to detect water on the floor and a camera that allows the person to view who is at the door and let them in using a cell phone. The smart house at the University of Florida relies on a centralized computer network to deliver electronically coordinated assistance” (Ascribe 2003).

Security

In order to maintain the security of the home many home automation systems integrate features such as remote keyless entry systems which will allow seniors to view who is at the door and then remotely open the door. Home networks can also be programmed to automatically lock doors and shut blinds in order to maintain privacy.

Emergency assistance systems and tools

Emergency assistance for the elderly and disabled can be classified into three categories: First, Second, and Third Generation emergency assistance systems or tools (Celler 1999).

First generation

These simple systems and tools include personal alarm systems and emergency response telephones that do not have to be integrated into a smart home system (Celler 1999). A typical system consists of a small wireless pendant transceiver to be worn around the neck or wrist. The system has a central unit plugged into a telephone jack, with a loudspeaker and microphone. When the pendant is activated a 24-hour control center is contacted. Generally the 24 hour control centre speaks to the user and identifies that help is required e.g. Emergency services are dispatched. The control centre also has information of the user, e.g. medical symptoms, medication allergies, etc. The unit has a built in rechargeable battery backup and the ability to notify the control center if the battery is running low or if the system loses power. Modern systems have active wireless pendants that are polled frequently advising battery, and signal strength status as older style pendant could have a battery that has failed rendering the pendant useless when required in an emergency.

Second generation

These systems and tools generate alarms and alerts automatically if significant changes are observed in the user's vital signs (Celler 1999). These systems are usually fully integrated into a home network and allow health professionals to monitor patients at home. The system consists of an antenna that a patient holds over their implanted cardiac device to transmit data for downloading over the telephone line and viewing by the patient's physician. The collected data can be accessed by the patient or family members. Another example of this type of system is a Smart Shirt that measures heart rate, electrocardiogram results, respiration, temperature and other vital functions and alerts the patient or physician if there is a problem (Bowie 2000).

Third generation

These types of systems would help the elderly and disabled deal with loneliness and depression by connecting them with other elderly or disabled individuals through the Internet, reducing their sense of isolation (Celler 1999).

Reminder systems

Home automation systems may include automatic reminder systems for the elderly (Cheek 2005). Such systems are connected to the Internet and make announcements over an intercom. They can prompt about doctor's appointments and taking medicine, as well as everyday activities such as turning off the stove, closing the blinds, locking doors, etc. Users choose what activities to be reminded of. The system can be set up to automatically perform tasks based on user activity, such as turning on the lights or adjusting room temperature when the user enters specified areas. Other systems can remind users at home or away from home to take their medicine, and how much, by using an alarm wristwatch with text message and medical alert. Reminder systems can also remind about everyday tasks such as eating lunch or walking the dog.

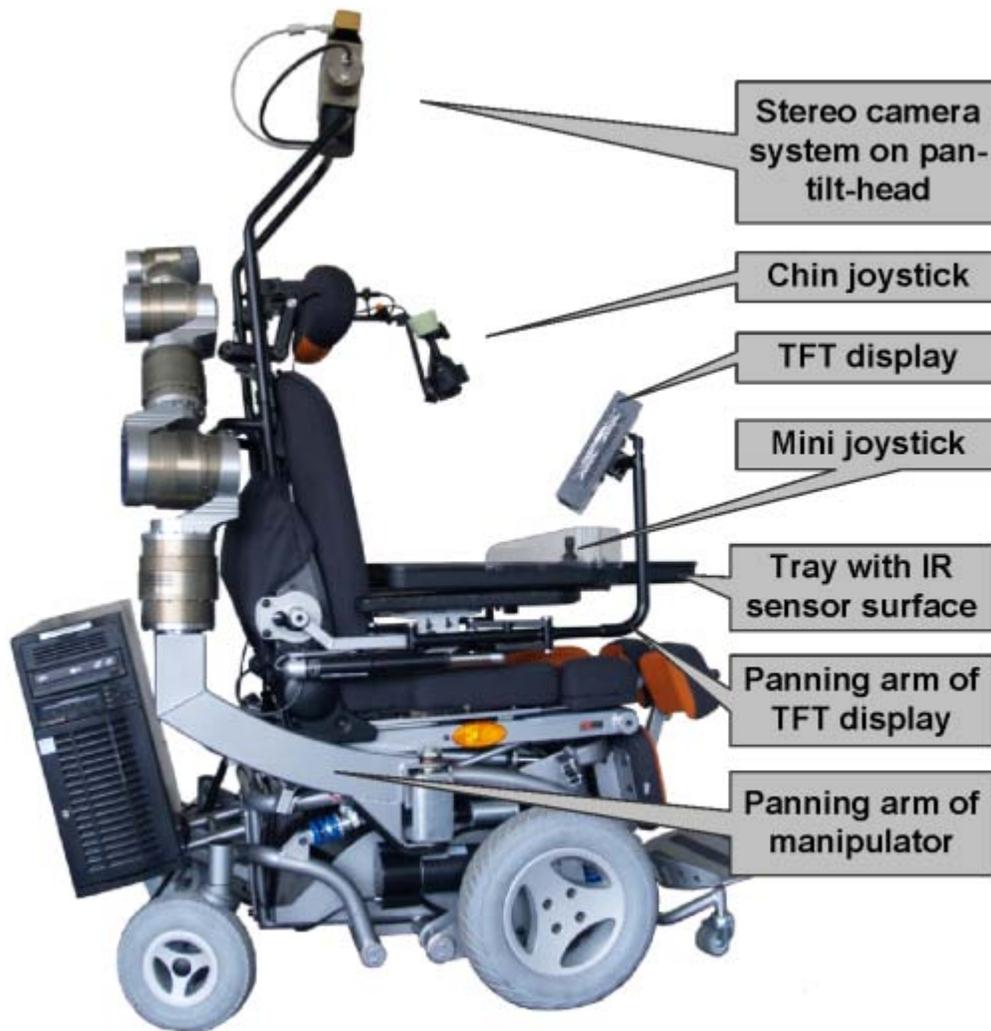
Some communities offer free telephone reassurance services to residents, which includes both safety check calls as well as reminders. These services have been credited with saving the lives of many elderly and senior citizens who choose to remain at home.

Medication Dispensing and Spon-feeding

Smart homes can implement medication dispensing devices in order to ensure that necessary medications are taken at appropriate times (Cheek 2005). Automated pill dispensers can dispense only the pills that are to be taken at that time and are locked; versions are available for Alzheimer's patients that have a lock on them (Cheek 2005). For diabetic patients a talking glucose monitor allows the patient to check their blood sugar level and take the appropriate injection (Cheek 2005). Digital thermometers are able to recognize a fever and alert physicians. Blood pressure and pulse monitors dispense hypertensive medications when needed.

There are also spon-feeding robots.

Home robotics



The Care-Providing robot FRIEND.

Domestic robots, connected to the domotic network, are included to perform or help in household chores. Dedicated robots included robots helping to administer medications and alerting a remote caregiver if the patient is about to miss his or her medicine dose (oral or no-oral medications).

The Care-Providing robot FRIEND developed at the Institute of Automation (IAT) of the University of Bremen is a semi-autonomous robot designed to support disabled and elderly people in their daily life activities, like preparing and serving a meal, or reintegration in professional life.

Challenges

The recent advances made in tailoring home automation toward the elderly have generated opposition. It has been stated that “Smart home technology will be helpful only if it is tailored to meet the individual needs of each patient” (Cheek 2005). This currently creates a problem because many of the interfaces designed for home automation “are not designed to take functional limitations, associated with age, into consideration” (Cheek 2005). Another problem that has been presented involves making the system user-friendly for the elderly who often have difficulty operating electronic devices. The cost of the systems has also presented a challenge, because although the systems would be cheaper than the costs of a long-term health care facility, the U.S. government currently provides no assistance to seniors who choose to install these systems (in some countries as Spain the Dependency Law includes this assistance).

The biggest concern expressed by potential users of smart home technology is "fear of lack of human responders or the possible replacement of human caregivers by technology" (Cheek 2005), but home automation should be seen as something that augments, but does not replace, human care.