Occupancy sensors deliver lighting on demand

Abstract

Sensors are wonderful things. Many of us have one by the front door, which turns lights on automatically when we get home late at night. This reassures us that no-one is lurking in the shadows, and gives us enough light so we can see to unlock the door.

In the home, sensors provide benefits including convenience, security and cost savings (through having lights on only when required). In commercial buildings, these same benefits are multiplied many times over.

Lighting typically accounts for up to 40% of the energy used in commercial buildings, and the cost of that energy is creeping up year by year. One of the easiest ways to reduce energy use and to cut costs (and emissions) is to turn off lights when they are not required.

Many of today's commercial lighting and building automation systems use occupancy sensors to turn lights on and off based on whether or not an area is occupied. Not only does this reduce energy consumption and save money, it also helps buildings to comply with the "automatic shut-off of building lighting" requirements of energy codes such as ASHRAE 90.1 and California Title 24.

This paper looks at the benefits that occupancy sensors can provide, and how those benefits can be further enhanced by removing the wires.

What is occupancy sensing?

Manual light switches exist so that humans can turn lights on and off. Most of us are good at turning lights on, but we often forget to turn them off when leaving a room.

That's where occupancy sensors come in.

Originally designed for use with security systems, occupancy sensors have been refined and enhanced to control lighting and HVAC in commercial and residential spaces.

These sensors detect activity within a specified area, and provide convenience by turning lights on automatically when someone enters. They also reduce costs and energy use by turning lights off soon after the last occupant has left.

Using occupancy sensors to turn lights off when areas are unoccupied helps to reduce energy waste and costs by between 35% and 45% (according to the California Energy Commission).

Most sensors are configurable, and can be adjusted for the required levels of sensitivity and accuracy. This helps to avoid false triggering, which can be caused by things like air movements from HVAC vents and the movement of warm air in front of a sunny window. Some sensors also allow you to set time delays between the sensor detecting a lack of occupancy and turning the lights off (usually between 10 and 15 minutes).

Occupancy sensors are best suited to areas where people spend variable amounts of time and often forget to turn lights off when leaving, such as meeting rooms and private offices.

Different types of occupancy sensors

There are two main types of occupancy sensors used with lighting and building automation systems: Passive Infrared (PIR) and Ultrasonic.

Passive Infrared (PIR)

PIR sensors detect occupancy by passively measuring the infrared radiation being emitted from the objects in their view. Motion is detected when an infrared source (such as a person) passes in front of another infrared source with a different temperature (such as a wall). The PIR sensors react to the changes in heat patterns created by the moving person and turn lights on and off accordingly.

A curved faceted lens defines the field of view as a fan-shaped series of vertical and horizontal "cones" of detection projected from the sensor. The farther an occupant is from the sensor, the wider the gaps between these cones, and the larger a motion needs to be to trigger the device.

PIR sensors are highly resistant to false triggering, but are strictly line-of-sight and cannot "see" around objects or over partitions.

These sensors are ideally suited to areas with little or no obstruction, such as small offices and meeting rooms.

Ultrasonic

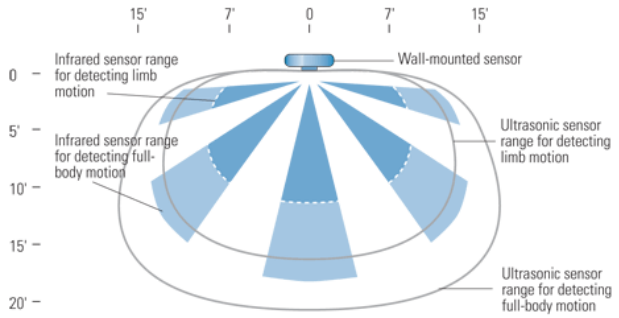
These sensors emit an inaudible high-frequency (25-40 kHz) sound wave, which bounces off objects, surfaces and people. When the waves bounce back to the sensor, their frequency is measured. These sensors can "see" around objects and surfaces as long as the surfaces are hard enough to bounce back the sound waves for detection.

Ultrasonic sensors are sensitive to all types of motion and generally have zero coverage gaps (being able to detect movements not within line of sight). However, they are more expensive than PIR sensors, are more prone to false triggering, and may interfere with other ultrasonic sensors or hearing aids.

These sensors are best suited for indoor use, in areas that are large, contain obstructions, or are unusually shaped such as open offices, large conference rooms, and restrooms.

Dual technology/hybrid

Hybrid sensors combine both PIR and ultrasonic technology to deliver maximum reliability and coverage with a minimum of false triggers.



Source EnergyStar (www.wnergystar.gov)

These sensors allow for wide coverage and are suitable for a wide range of applications. However, they are more expensive than PIR or ultrasonic sensors, and typically require more adjustments.

Hybrid sensors are a good choice for large open areas, and for areas with unusual occupancy patters or work requirements.

Vacancy and motion sensors

These two additional types of sensors are similar to occupancy sensors, but serve slightly different purposes.

Vacancy sensors have only one automatic feature, which is to turn lights off when an area is vacated. Lights must still be turned on manually. These sensors are useful for areas such as restrooms and stairwells. They can also be used to further save energy in spaces such as private offices where occupants may choose to keep lights off when there is enough ambient light for the tasks being performed.

Motion sensors are typically used for security rather than for building and lighting control. These sensors respond only to moving objects. If an individual in a room remains fairly still (for example, someone working at a desk), the motion sensor will often cease to "see" them. These sensors are also typically slower to react than occupancy sensors. Therefore, motion sensors are not recommended for use in lighting control systems.

Obtaining the best results

Occupancy sensors can be mounted on the ceiling or on the wall (like a light switch). Careful planning is required to ensure sensors are located where they will

detect occupancy and occupant activity in all parts of the room.

In a small area, such as a private office, a single sensor will usually provide sufficient coverage. In larger spaces, multiple sensors will likely be needed to obtain full coverage. Be aware also that coverage and range can vary between sensor manufacturers. (Check the sensor literature for full details.)

It is important to get the sensitivity setting correct, which determines the amount of movement required to trigger lights to turn on, stay on, or turn off. If the sensitivity is too high, the sensor might turn lights on even though the area is unoccupied. Setting it too low might leave your occupants in the dark!

Time delay settings specify the amount of time the sensor waits between perceiving the room is empty and turning the lights off. Shorter time delays produce higher energy savings, but may shorten lamp life due to more frequent switching. Longer delays avoid continual on-off cycles in areas where occupants enter and leave frequently. They also help to overcome brief periods when an occupant is moving very little. Manufacturers often recommend a minimum time delay of 15 minutes.

It is important to make sure building occupants are educated in the use of occupancy sensors and the lighting control system. Get them to inform you when offices are rearranged or furniture moved so that the sensors can be adjusted and the lighting system "tweaked" if required.

You also need to ensure that the lamps you are using are suitable for occupancy sensing. For example, HID lamps require long warm-up times, so are not suited to being switched on and off by occupancy sensors. CFLs can also be sensitive to rapid on/off cycling in situations where only brief illumination is required. Better results for these lamps may be obtained by using scheduling to switch between low power and full power (dimming). Find out more in Daintree's white paper: *Lighting schedules offer timely savings*.

Fine-tuning your system

Occupancy sensors can provide impressive savings, but they are only the first step in making your lighting system more sustainable. You can further reduce costs and energy usage by integrating other technologies including

- scheduling
- photosensors
- timers
- switches

Many of today's lighting control and building automation systems provide **scheduling**, which automatically turns on, off, or dims lights at specified times of the day. These scheduled lighting events can apply either to all lights within a building, or only to those in a specific area. Scheduling is ideal for areas with predictable usage patterns (for example, building entrances and open plan offices).

Photosensors measure natural light levels, and can be used to dim or brighten the amount of artificial light supplied. This helps not only to reduce energy usage and costs when natural light is abundant, but also to reduce the amount of heat being emitted by electric lights, which in turn, can help save money on air conditioning costs. Find out more in Daintree's white paper: *Harvest daylight and reap rewards*.

Timers turn lights on for a preset period of time. These are useful to allow access to buildings outside of normal office hours, and for low-traffic areas where people typically spend a predictable amount of time such as stairwells and storage cupboards.

You can reduce costs further by having the first person who arrives each morning to manually **switch** on the lights. This helps to avoid wasted energy from having lights on when the building is not occupied. The lighting control system would then manage the rest of the on/off/dimming events for the day.

Removing the wires

Many traditional building and lighting control systems are fully wired, with all lights, sensors and switches hard-wired to a central controller (or to a gateway that facilitates communication between the lighting network and lighting control software). Because of the cost of the wiring, and the complexity of covering a large area, these often operate as a number of self-contained systems (for example, one per room or floor).

Newer lighting systems take advantage of wireless mesh networking, which allows the lights, sensors, switches and the central controller to communicate with each other without the need for wires. Removing those wires provides more flexibility in terms of where switches and sensors can be placed, and also makes it more affordable to include additional sensors in your network (allowing you to obtain more granular information about occupancy and illumination levels).

Wireless mesh also supports more flexible and easier control of larger systems with more devices. It allows you to run your lighting control solution as a single system that covers an entire building (or multiple buildings), as well as room by room (or floor by floor) deployments. This approach provides a system-wide view of operations, current power usage, savings, and more.

Wireless retrofits

Not only is wireless a good choice for new buildings, it is also ideal for retrofits and redesigns.

Retrofits provide the potential for huge cost and energy savings. More than 75% of the estimated five million commercial, industrial and institutional buildings in the US were built at least 20 years ago. Because of their age, many were grandfathered in when stricter energy-use requirements were introduced in the last decade. Updating the lighting in these buildings to include scheduling, daylight harvesting and occupancy controls is an affordable and intelligent way to deliver energy efficiency and improved system performance, and to help bring these buildings into the 21st century.

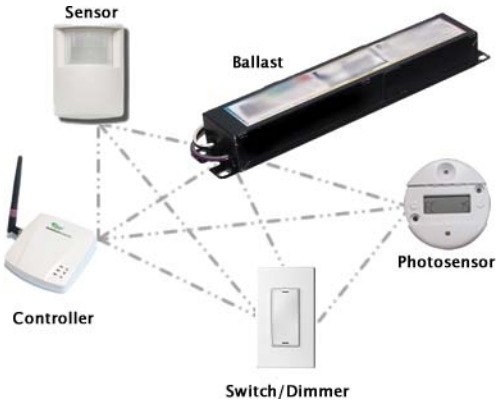
Existing wired dimmable ballasts and luminaires can often be incorporated into the new lighting system by fitting them with "wireless adapters" that allow them to wirelessly communicate with the rest of the mesh network. Removing the need to run control wiring from every fixture, control and sensor back to the central controller not only saves time and money, it can also help to minimize disruption in buildings that are occupied during the retrofit.

Once the wireless lighting system is installed, control zones and lighting behavior can be changed by simply reconfiguring the lighting software. Sensors and controls are also much easier to add and relocate when they don't have wires.

How wireless mesh networks work

This type of network consists of a mesh of interconnected devices (e.g. luminaires, switches, controllers). Each device contains a small radio transmitter that it uses for communication. These transmitters can be either built in to the device or can be fitted externally.

In a wireless mesh network, each device is typically connected through at least two pathways, and can relay messages for its neighbors.



Data is passed through the wireless network from device to device using the most reliable communication links and most efficient path until the destination is reached. Two-way communication also helps to increase reliability, by allowing devices to acknowledge receipt of data and to require retransmission of data not received.

The mesh network is self-healing, in that if any disruption occurs within the network (such as a device failing or being removed), data is automatically re-routed. The built-in redundancy of having multiple pathways available helps to make the mesh network both robust and reliable.

Mesh networks are also highly scalable, in that you can extend the network simply by adding more devices. The network's self-configuring capabilities identify when a device is added: working out what type of device it is, where its neighbors are, and what the best path is through the network. Weak signals

and dead zones can also be eliminated simply by adding more devices to the network.

You can find out more about the benefits of mesh networks in Daintree's white paper: *What's so good about mesh networks?*

Regulations and initiatives

Lighting upgrades are extremely cost-effective, generally providing an ROI in two to five years (with savings in both operations and maintenance costs).

This is sweetened further by the incentives many governments are offering to promote green building and retrofits, and to stimulate the building industry after the recent economic downturn.

In the US, refer to the DOE's Database of State Incentives for Renewables & Efficiency (DSIRE) at http://www.dsireusa.org/ for details about available incentives.

Some utilities also provide credits for lighting control solutions that support demand side load-shedding. A lighting control solution can be configured to automatically react to demand response events from utilities, and adjust lighting to pre-set acceptable levels to take advantage of cost savings.

Regulations and codes

Governments around the world are introducing regulations and initiatives aimed at making buildings greener and more sustainable. These include lighting control and scheduling standards and codes for both new buildings and retrofits (such as Title 24, IESNA and ASHRAE).

Codes are being updated regularly to become more stringent, and all are advocating the use of some form of automated lighting control that includes scheduling and occupancy control (for automatic shutoff of building lighting) and daylight harvesting. While these are still guidelines and recommendations in many places, they are gradually making their way into mandatory building requirements.

Find out more about these codes:

- Building energy codes program (including status of state energy codes): www.energycodes.gov
- California Energy Commission (CED) Title 24: www.energy.ca.gov/title24
- Illuminating Engineering Society of North America (IESNA): www.iesna.org
- American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE): www.ashrae.org

Certification

Lighting control systems need to be certified to qualify for many of the available government incentives.

One of the leading certifications is LEED (Leadership in Energy and Environmental Design). Within the US, LEED is the nationally accepted benchmark for the design, construction and operation of high performance green buildings.

You can find out more at www.usgbc.org/leed.

Wireless pros and cons

Mesh networks provide many benefits for lighting control, and removing the wires provides even more including increased flexibility and reduced installation costs. But no single solution is perfect for everyone. Below is a summary of both the pros and cons of wireless mesh lighting control:

- **Cost:** Installation costs are greatly reduced without the need to run control wires from each device back to the central controller. However, wireless sensors and controls are sometimes more expensive than their wired counterparts, so some of the money you save on wiring may go back into purchasing the wireless devices.
- **Security:** Both wired and wireless solutions provide effective security. Most wireless lighting technologies use 128-bit Advanced Encryption Standard (AES) security for communications. This security is robust enough that, in June 2003, the US Government announced that AES may be used to protect classified information.
- **Scalability:** Wireless mesh solutions support more devices over greater distances than wired ones, which makes wireless ideal for multi-office and multi-floor installations. The nature of mesh

networks means that simply adding new devices can extend the communication coverage of the network. And the wireless nature of the controls allows you to place them in areas that were previously difficult or costly to access.

- **Reliability:** Both wired and wireless networks use mature technologies that offer great robustness and reliability. There is the potential of radio interference and data loss with some wireless technologies that share the same radio frequency (such as Wi-Fi® and ZigBee®). Fortunately, this problem is easily avoided for your lighting solution by selecting channels within the radio frequency that are not commonly used by other wireless devices. You can further protect yourself by selecting a wireless mesh technology like ZigBee, which can automatically switch to a new channel if it detects interference on the current channel.
- **Flexibility:** This is one of the biggest benefits of wireless. Devices can be installed where they will provide maximum benefit instead of where it is easiest to run wires. Devices are also grouped into "zones" using addressing and software rather than hard wiring, which allows changes to be made at any time through simple software reconfiguration (no costly or disruptive rewiring required).
- **Complexity:** Wireless allows you to avoid the complexity of connecting wires from hundreds (or thousands) of devices back to a controller, but that comes at a price. It can be more difficult to locate a device when you don't have wires to follow. The good news is that tools are available to help you locate and identify devices during installation and commissioning, and for the ongoing operation, monitoring and maintenance of the system.

Summary

Cost and energy savings are major design considerations for modern lighting systems. Wireless occupancy sensing and lighting control provides all this and more.

Removing the wires from the lighting system provides additional benefits, including greater flexibility in where sensors and switches can be placed, significant savings in installation (by avoiding the expense and disruption of wiring), and the ability to control and monitor large lighting installations as a single system.

You not only save money on the installation and usage costs, but can also take advantage of the tax incentives offered by many governments to encourage greener buildings and retrofits. And major building standards such as the LEED design rules and Green Star ratings require Occupancy Sensing if a high rating is to be achieved.

In summary, wireless occupancy sensing makes good sense.

About Daintree Networks

Based in Mountain View, California, Daintree Networks is a clean technology company that provides wireless control solutions for commercial buildings. Daintree has a strong background in wireless sensor and control mesh networking, with extensive knowledge and experience gained through its industry-standard design verification and operational support tool, the Sensor Network Analyzer (SNA). In addition to wireless embedded expertise, Daintree has put together a team of seasoned professionals from the lighting, telecommunications and networking worlds. Daintree's expertise and knowledge is now being focused on the development of cost-effective building automation systems. These provide benefits including reduced energy consumption, costs and carbon footprint, compliance with new "green" building regulations, and cost savings available through government rebates and the ability to take advantage of demand response programs.

Daintree's Wireless Lighting Control Solution (WLCS) allows lighting manufacturers to speed their time to market, and enables them to deliver powerful, comprehensive, flexible, and reliable wireless lighting control systems for commercial buildings. For more information, visit www.daintree.net or email sales@daintree.net

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Daintree Networks Inc
1503 Grant Road, Suite 202
Mountain View, CA 94040 U.S.A

(w) www.daintree.net
(e) sales@daintree.net
(p) +1 (650) 965-3454