DaintreeNetworks

White Paper

Applying Mesh Networking to Wireless Lighting Control

www.daintree.net

Abstract

Recent advances in wireless communications standards and energy-efficient lighting equipment have made it possible to effectively combine mesh networking with lighting control to create reliable, large-scale wireless lighting networks. The results are impressive, providing enhanced control and reductions of up to 70% in lighting energy consumption for commercial and industrial buildings. Considering that lighting can account for up to 40% of the electrical cost in commercial buildings, this reduction translates into significant cost and energy savings.

This paper describes how standards-based mesh networking works, and the benefits of a wireless mesh approach. It then looks at how wireless mesh networking can be used to deliver effective and affordable lighting control solutions.

What is a mesh network?

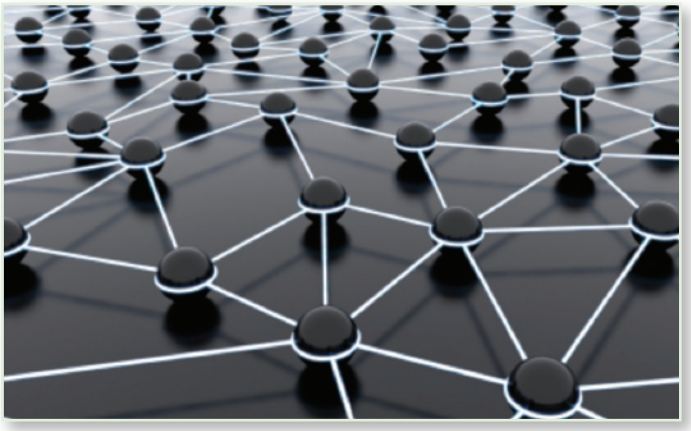
The term "mesh networking" describes a network architecture that is commonly used in a variety of technologies, both wired and wireless. One of the easiest ways to understand the concept of mesh networking is to look at two of the best known mesh networks: the public switched telephone network (PSTN) and the Internet.

Both of these networks provide communications between two end devices (for example two phones or two computers). Information is transferred between the two end devices through a series of intermediary devices including routers (which are able to both receive and retransmit messages) and gateways (which provide communication links between different networks and enable messages to be passed from one network to the next).

There is no set path through the network for messages to follow. Each router and gateway within the mesh is typically connected through two or more devices, which provides a number of different paths available for network communications. The route between two end devices often goes through multiple "hops" – in other words, communication passes through other devices to cover long distances with little or no degradation.

One of the primary benefits of this architecture is that if an intermediary device fails, is offline, or is busy, the message can still get through via an alternative path. Mesh networks look for the most efficient path available and will automatically re-route messages to avoid any failures. This is why mesh networks are often referred to as "self-healing": the network automatically works around problems that it encounters.

Mesh networks also provide self-configuration, in that when a new device is added (or an existing device is moved) the network automatically works out what type of device it is (e.g. router or end device), where its neighbors are, and determines the best path through the network. After devices are configured, they regularly poll their neighbors to collect information about signal strength and possible errors, so that they can recalculate transmission routes if required.



Mesh network device types

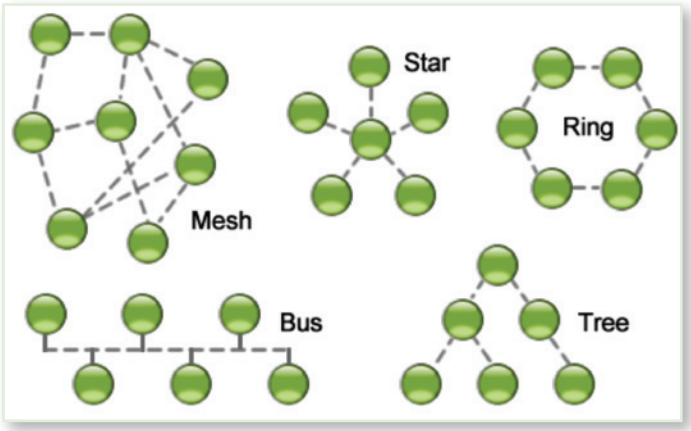
Mesh networks typically contain the following types of devices:

- **End devices** can be the start or destination of a message, but cannot forward messages for other devices. In most mesh networks, end devices are those that users interact with directly, such as telephones and computers.
- **Routers** can be the start or destination of a message, and can also forward messages for other devices. Routers extend network area coverage, dynamically route around obstacles, and provide backup routes in case of network congestion or device failure.
- **Coordinators** are special types of Routers that are used by some mesh networks (such as the ZigBee® wireless standard). Coordinators perform the same functions as normal Routers, plus have added intelligence allowing them store and manage information about the network including routing tables and security keys. Coordinators can also provide Gateway functionality.
- **Gateways** provide communication between different networks, for example an office LAN and the Internet. Gateways often contain capabilities such as firewall security and protocol translation, which allows different types of networks to communicate.

Mesh and other network topologies

Topology refers to the configuration of the hardware devices that make up a network and how the data is transmitted through that configuration.

The image below shows some of the more popular network topologies in use today.



Unlike mesh, the other topologies do not offer alternative routes through the network. That means that if one of the network devices fails or suffers congestion, network traffic will slow and may even stop. While this may be acceptable (and sometimes even desirable) in some types of networks, it is not suitable for many applications. For example, energy provision and management, commercial building automation, lighting control, and industrial automation all require high levels of reliability and resiliency.

In addition, since any device in a mesh network can potentially route messages from other devices, the design of that network is extremely flexible. Mesh networks lend themselves to large, complex networking applications with many devices.

Wireless mesh networks

Connections between devices within a mesh network can be either wired or wireless, depending on the technology used for communications.

As wireless technologies have matured and wireless radios have become less expensive, the list of devices that are able to communicate wirelessly is growing rapidly.

Wireless mesh benefits

Removing the wires provides a number of benefits over wired mesh networking:

- **Flexibility:** The physical placement of a wireless mesh device is extremely flexible—as long as it is within communications range of other devices within the network, it can be placed nearly anywhere. For control networks, this means devices can be placed in the most logical or convenient location rather than where it is easiest to run control wires. Areas that would be difficult, expensive, or even impossible to cover within a wired network are accessible within wireless networks.
- **Cost:** Wireless removes the expense and time involved in installing and maintaining dedicated wiring to each device within the network. This makes wireless mesh a very affordable solution for retrofit applications, in that it removes the need (and associated costs and disruption) to run new wiring through existing walls and ceiling spaces.
- **Scalability:** A single mesh network can support thousands of individual devices. Adding new devices can be as simple as putting the device where you want it, and then turning it on.
- **Reliability and robustness:** A mesh network can be improved in many ways by adding more devices – extending distance, adding redundancy, and improving link quality and the general reliability. This is particularly easy with wireless networks, where administrators can add, move and remove devices without needing to perform elaborate site surveys or worry about wiring to communicate between devices.

Using standards for wireless communications

Wireless communications standards are used to define and structure the messages between devices in a wireless network: telling networks which radio frequencies to monitor, how to read the messages they receive, how to provide security and reliability, and more.

A number of different wireless networking standards exist, each of which is aimed at a different application and type of communications. For example, wireless Internet access requires high data rates (to enable large amounts of data to be uploaded and downloaded) and is able to accept minor connection delays. The Wi-Fi standard (based on IEEE 802.11) was designed to meet these needs.

On the other hand, building or lighting automation systems transmit much simpler messages (e.g. turn light on, turn heating down 2 degrees). These messages do not require such high data rates, but they do require a near-instant connection speed to ensure that when you turn on a light switch it comes on immediately. An added benefit to lower data rates is that messages take less power to send and receive. That means that building and lighting automation devices such as occupancy sensors can have longer battery life, or

in some instances, not require batteries at all. The ZigBee standard (based on IEEE 802.15.4) was designed to meet these needs.

In general, all products which communicate wirelessly can adopt one of two types of communications protocols:

- **Open standards,** which are agreed upon, adopted, or approved either universally or by a large group of interested parties. They encompass the ideas of the many, as well as the concepts of compatibility, interoperability, and agreement. This typically leads to lower component prices due to high volume, and greater choice based on wide adoption.
- **Proprietary protocols or closed standards,** which are privately developed and owned to meet specific application needs or create barriers to market entry. They are sometimes made available to others (as closed standards) under conditions such as license terms or use fees, and are often protected by restricting the manufacture of the key components required to implement the standard.

Open standards and interoperability

One of the driving forces behind open standards is creating interoperability.

When different manufacturers adhere to the same open standards in designing and building their products, the result is that company A's switches will work seamlessly with company B's ballasts and company C's sensors. This provides greater choice and flexibility for consumers, who are able to mix-and-match components from different manufacturers to put together their ideal system.

Interoperability is especially important in large-scale, mixed-device networks. A small-scale, closed-loop network can operate effectively with a proprietary protocol because all devices are intended to be supplied by a single manufacturer. In large-scale mesh networks containing many types of devices, on the other hand, as the network grows and adds devices (both new types, and from new manufacturers) the standards ensure that all devices will work together.

This also allows manufacturers to partner with each other and offer more fully-featured solutions. For example a building control solution could consist of company A's lighting system, company B's HVAC system, and company C's security system—all of which are compatible with company D's smart meters and energy management system. The fact that they work together via an interoperable standard broadens the market opportunities for each company.

ZigBee open standard

ZigBee is an open standard that was created to address the market need for a cost-effective, standards-based wireless networking solution that supports low data-rates, low-power consumption, security and reliability. This makes it ideal for a wide set of machine-to-machine and control applications such as commercial building and home automation, lighting control, energy management and telecommunication services.

The robustness of the ZigBee standard, combined with the benefits of wireless mesh networking, make ZigBee ideally suited for commercial building automation and lighting control solutions. This has made it the wireless standard of choice for today's emerging commercial lighting control solutions.

You can find out more about ZigBee from the ZigBee Alliance web site at www.zigbee.org.

Wireless mesh for lighting control

The benefits of lighting control solutions have been long recognized, especially for commercial buildings where lighting can account for up to 40% of electrical costs. Combining centralized control of illumination levels with sensor-based automation (such as using sensors to turn lights off in unoccupied rooms) is an ideal way to manage energy consumption and reduce costs. In fact, lighting control solutions have been shown to reduce lighting energy consumption in commercial and industrial buildings by up to 70%. (You can find out more about the applications and benefits of lighting control solutions in Daintree's white paper The value of wireless lighting control.)

More recently, many utilities have begun to offer demand management programs, where they provide rewards and incentives as a way to encourage companies to reduce their energy consumption. This has added to the value of lighting control systems, enabling them to automate the process of responding to these programs.

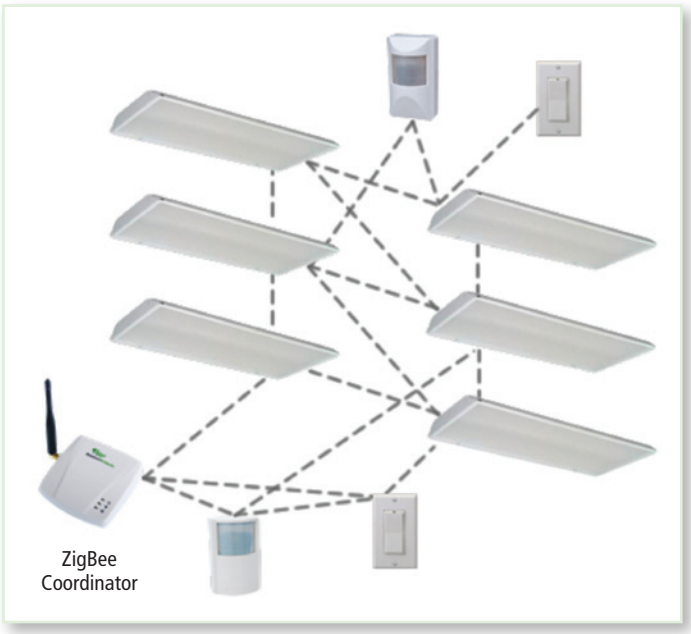
In the past, the main barrier for many building owners/operators in implementing lighting control systems was the cost and complexity of installing and maintaining control wiring (especially in retrofits). Wireless mesh networking has removed this barrier.

Using wireless mesh to control commercial lighting

The strongest and most reliable mesh networks are those that contain a large number of devices, each of which is within radio frequency range of multiple other devices. The density of lights, switches and sensors within commercial buildings makes lighting control a perfect application for wireless mesh networks. The lighting mesh can also serve as a backbone to provide communications for other compatible building control applications (such as HVAC and security), adding the extra wireless nodes these applications previously lacked.

In a wired lighting system, all lights, sensors and switches are hard-wired to a central controller, or to a gateway that facilitates communication between the lighting network and lighting control software.

By contrast, in a wireless mesh system each device can communicate with the controller wirelessly, using the multiple paths available through the mesh. The lighting control system recognizes each device by a digital address, eliminating the need for physical wiring. So when the controller receives a message from an occupancy sensor that has been triggered, it knows where within the network that sensor is located, and which lights should be adjusted in response to the sensor event.



The digital addressing used by wireless networks also makes it quick and easy to create and modify lighting zones—requiring simple software configuration instead of physical wiring. And devices aren't limited to communicating only with other devices within the same zone (as is often the case with wired networks). Communications follow the most efficient path through the mesh, regardless of which zone individual devices belong to.

In a wired network, there are also physical limits on the number of devices that can be included within a zone or can be managed by a single controller. For example, the wired Digital Addressable Lighting Interface standard typically limits the number of devices per controller to 64. By comparison, wireless mesh networks such as ZigBee are able to support hundreds of devices per controller and thousands per system.

Mesh networks can also be bi-directional, providing two-way communications throughout the system. Not only can the controller send requests to a light telling it to turn on, off or dim, the light can also respond with information such as its current state and energy usage.

Wireless for retrofits

As mentioned previously, one of the major inhibitors for installing a lighting control solution has been the cost of running control wires to every light, sensor, and switch within the system.

Because of the labor and related costs of the wiring and the complexity of covering a large area with sensors and other control devices, these systems are typically very expensive to implement. Beyond the equipment costs, simply installing wiring to connect a traditional wired lighting control system can cost as much as $2.00 per square foot. This has historically kept many buildings from taking advantage of full lighting control retrofits, and often limited the scope of lighting controls to individual self-contained systems (for example, one per room or floor).

Wireless communication removes the need to physically connect lights, sensors and switches to each other, reducing lighting control costs and improving capabilities. This is especially important for retrofits, where access to wires within walls and plenums, and introduction of new wires, can be difficult, expensive, and in some cases even impossible.

You can find out more in Daintree's white paper Lighting retrofits, with no wires attached.

Benefits of wireless mesh for lighting control

All of the benefits of wireless mesh listed above make them attractive for use in lighting control systems. In addition, wireless mesh networks are an especially good fit for lighting control for several reasons:

- **Ease of installation:** With wireless, there is no need to run control wires and crawl about in wall and ceiling spaces. And wireless mesh networking was designed to handle many of the network formation tasks (such as security). Automated commissioning techniques can make it even quicker and easier to get the network up and running once it has formed.
- **Scalability and Reliability:** Lighting networks can be very large in scale, encompassing hundreds or even thousands of lighting devices located within communicating distance from one another. Mesh networks perform well in this kind of environment, with the high node code actually improving the health of the network since there are more potential communication paths.
- **Reduced maintenance:** The network's self-configuring and self-healing capabilities help to reduce the manual maintenance required. Mesh networks can also automatically detect and troubleshoot any problems that do occur.
- **Bi-directional:** The mesh network is capable of bi-directional communication, which allows the collection of information about lighting energy use, events (such as manual switch use or occupancy detection) and device performance.

Summary

Lighting control is an effective way to reduce costs and energy usage in commercial buildings—and wireless mesh networking provides a better way to implement lighting control.

Wireless mesh technology enables lighting control solutions that provide reliability, security, flexibility and can scale to control large lighting networks. And as interoperability becomes more important, open standards like ZigBee provide the critical ability to mix and match devices from different vendors and combine a lighting solution with other standards-based wireless building automation systems (such as HVAC and security).

In short, wireless mesh networks deliver on promise of lighting control, offering solutions that improve energy usage and control with less cost and complexity than ever before.

About Daintree Networks

Daintree Networks is a clean technology company using wireless innovation to improve energy management within commercial buildings. Daintree provides technology for powerful, standards-based wireless lighting control solutions that deliver substantial lighting energy efficiency improvements in a more cost-effective way than ever before.

Since its founding in 2003, Daintree Networks has been a pioneer in wireless mesh networking, with nearly 400 customers using its industry-standard design verification and operational support tool. The company has brought this extensive experience to bear in developing the industry's first truly interoperable platform for wireless lighting controls. For more information, visit www.daintree.net.

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