White Paper
Integrating Wireless Communications and Controls Into Lighting Fixtures

Abstract

Wireless is fast becoming the preferred communications & controls technology for lighting. This is especially true for large-scale, networked lighting controls solutions, due to the cost and architectural advantages of wireless communications in these complex installations.

And yet, many lighting vendors are at a loss when it comes to the steps involved in integrating wireless networking into their devices in order to take advantage of the new opportunities this technology presents. Wireless expertise has not traditionally been part of the toolset of lighting manufacturers.

The purpose of this white paper is to de-mystify the process of adding wireless controls / communications to lighting products. It will discuss the various options in wireless integration for lighting manufacturers, as well as the key considerations and tradeoffs involved in designing a wirelessly integrated lighting product. Although this paper is primarily intended for fixture and power supply (ballast / driver) manufacturers, many of the same considerations hold true for manufacturers of sensors, wall switches and other in-building controllable devices.

Advantages of Integrated Wireless

As the capabilities of lighting controls systems have grown, so has the complexity of reaching and communicating with the fixtures, sensors, wall switches and other devices that are part of the system. In order to effectively control a fixture or other device, a central system must be able to communicate with it. Wired systems bridge this gap with dedicated control wiring – but physical layouts or infrastructure often limits the ability of wired control solutions to reach and control every device.

Wireless networking is an effective solution, eliminating limitations of which devices can be controlled, where they can be placed, and so on. This is especially critical in order to realize the most advanced control strategies, and those that extend beyond lighting. For this reason, integration of wireless networking into fixtures and sensors has become an attractive proposition.

Wireless lighting controls systems provide a variety of benefits over their wired counterparts:

- **Flexibility:** The physical placement of a wireless 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 control wiring to each device within the network. This makes wireless networking 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. This cost advantage also exists for new construction, one reason being that wireless wall switches/dimmers eliminate the need for line voltage wires going down walls to switch boxes.

Fig. 1: Examples of Wireless Adapters

- **Scalability:** A wirelessly networked controls system 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.

- **Management and maintenance:** Wireless networking enables simplified control and management of lighting, using software rather than a hard-wired circuit structure. This means facilities managers can change settings, update strategies and even re-assign sensors and fixtures to zones as the needs of the space change, all without physical maintenance or re-wiring.

  By integrating wireless capabilities into fixtures, manufacturers look to capitalize on these advantages with customers, while reducing the per-fixture cost of offering controllable lighting. As more and more buildings look to take advantage of energy-saving controls, the question is no longer whether or not to integrate controls into the fixture, but when and how.

Comparing Five Options for Integrating Wireless Controls

Several options currently exist for integrating wireless communications capabilities into lighting products. These range from currently-available packaged products (in the form of an adapter or controller), to custom-built connectors, to individual wireless components. As with any component decision, there are many tradeoffs to consider when deciding among these options. Below, we describe each of the individual options, and discuss the tradeoffs.

1. Third-party Wireless Adapter: Some wireless lighting controls vendors (Daintree Networks included) provide a wireless adapter product for wireless integration with existing fixtures. This type of product is intended to connect externally to a power supply, and is placed either inside the fixture (in the ballast channel if appropriate) or outside. The adapter communicates wirelessly with the controls vendor's wireless network, and locally manages the fixture(s) it is connected to. While some adapters are intended to control individual fixtures, others can also be used to control a circuit.

By using standard connections (such as 0-10 low voltage cabling), an adapter enables fixture manufacturers to take advantage of wireless controls today without making any product changes or commitments. As a "two-box" solution, this is an appropriate place to start but most lighting manufacturers are likely to quickly move to other options in order to reduce cost. (See Fig. 1 for examples of Wireless Adapters).

- **Per-fixture cost:** The most expensive option if placed in-fixture; medium expense if placed outside to control multiple fixtures.
- **Engineering effort:** None.
- **Speed to market:** Available immediately.
- **SKU management:** No issue, although existing adapters may not work with all fixtures.

2. Third-party Wireless Adapter Built-in: Some fixture manufacturers take the solution above and go a step further, by building third-party adapters directly into a specialized fixture SKU at the point of manufacture. This removes some cost out of installation at the customer site. Still, this remains a "two-box" solution. Because the adapter is offered by a third-party, it may not meet the exact requirements of the fixture, or may be over-engineered for a specific application.

- **Per-fixture cost:** Expensive option, with some reductions in installation costs.
- **Engineering effort:** Minimal.
- **Speed to market:** Quick, although some re-certification may be required.
- **SKU management:** No issue, although existing adapters may not work with all fixtures.

3. Custom Wireless Adapter: Another option is for the fixture manufacturer to create their own specialized adapter, based on designs from a lighting controls vendor. As in the option above, this is a "two-box"

solution. However, since it can be built to the specific needs of the fixture manufacturer (including connectors, power source, etc.) it can be a more cost-effective and space-conscious solution.

- **Per-fixture cost:** Medium option.
- **Engineering effort:** Some custom engineering required.
- **Speed to market:** Medium. Manufacturers with strong product design capabilities could move quickly, although product certification is still required.
- **SKU management:** If designed properly, this option could solve SKU management issues by providing a wireless add-on for multiple SKUs.

4. Integrated Wireless Module: With this option, we begin to discuss building wireless electronics directly into the light fixture or power supply. Many off-the-shelf module providers offer wireless modules built for integration into OEM products. A wireless module typically consists of the microcontroller, transceiver and antenna on a printed circuit board.

In this case, the lighting manufacturer would purchase an off-the-shelf module and build it directly into their fixture or power supply internally. Much of the engineering component work would be complete, but the lighting manufacturer would still need some specialized expertise in order to build the module component into a new product (or set of products).

- **Per-fixture cost:** Low, although the module manufacturer still takes a profit on each unit.
- **Engineering effort:** Custom engineering and some wireless experience is required.
- **Speed to market:** Medium to long.
- **SKU management:** Could be an issue, as each fixture would need to be redesigned to accommodate wireless capabilities.

5. Integrated Wireless IC: This is the most truly integrated option – with a wireless radio "built-in" and fully integrated as part of the fixture. In this case, the lighting manufacturer would purchase an off-the-shelf wireless IC, and integrate the other required components (antenna, etc.) themselves. This is the most work-intensive but cost-effective option. In addition, manufacturers that already use electronic components within their fixtures or power supplies (such as LED drivers) can eliminate duplication of components to reduce costs further.

- **Per-fixture cost:** Lowest option.
- **Engineering effort:** Most difficult option. Custom engineering and wireless experience is required.
- **Speed to market:** Long.
- **SKU management:** Could be an issue, as each fixture would need to be redesigned to accommodate wireless capabilities.

These five options represent a logical progression. Many fixture manufacturers have chosen to start with a third-party solution to meet customer needs today, while beginning the longer-term engineering effort required to move towards one of the latter options.

		Per-Fixture Cost	Engineering Effort	Speed to Market	SKU Management
1.	Third-party Wireless Adapter	High	None	Fast	Good
2.	Third-party Adapter Built-In	High	Minimal	Fast	Good
3.	Custom Wireless Adapter	Medium	High	Variable	Best
4.	Integrated Wireless Module	Low	High	Slow	Variable
5.	Integrated Wireless IC	Lowest	Highest	Slow	Variable

Key Considerations in Integrating Wireless Technology

Although some of the above options can be quite simple, in the long term we expect that most fixture manufacturers will choose to offer one of the more tightly-integrated options – which are lower-cost but require more careful design analysis. This section will cover some of the key considerations when integrating wireless technology.

• The first and most important consideration when adding wireless technology is determining **which wireless communications protocol** to utilize. Although it is outside the scope of this paper to provide a full comparison of wireless networking protocols, we have listed below some of the more common options.

    - **ZigBee®** – a standard protocol built upon IEEE 802.15.4, featuring a low data rate, mesh networking, and bi-directional communications. ZigBee is one of the more popular options, especially for larger, centrally managed spaces and energy management applications.

    - **Proprietary 802.15.4** – several individual vendors offer options using communications built on IEEE 802.15.4 (similar to ZigBee), but with proprietary or vendor-specific protocols. (See standard v. proprietary, below.)

    - **EnOcean** – a protocol featuring a low data rate and energy harvesting capabilities (see power management, below.) Communications are uni-directional and not networked. EnOcean is one of the more popular options for individual rooms and other small spaces.

    - **Z-Wave** – a mesh networking protocol intended for low-data rate applications. Z-Wave is popular in home automation, but has limited applicability in commercial buildings.

    - **Wi-Fi** – a standard wireless protocol intended for high data-rate applications. Wi-Fi has had limited success in machine-to-machine automation (such as controls networks), and only in residential applications.

• Hand-in-hand with the decision of wireless technology is the decision of **standard v. proprietary** wireless protocols. When a fixture with integrated wireless communications joins a wireless controls system, that fixture inherently becomes part of a network. A key question to consider is: What else can be on that network, now and in the future? In other words, is there an ecosystem of other devices (sensors, dimmers, controllers, etc.) that communicate on the same network, or is it limited to a single vendor's products?

When the protocol being used is proprietary, the only devices that can be used with your fixture must be sold (or licensed) by a single vendor, now and in the future. This limits future growth for customers and introduces risk, but may be the right choice for manufacturers looking to commit to developing their own "closed" solution. With "open" or standard communications protocols, on the other hand, your wireless fixture joins an ecosystem of interoperable devices that can communicate with each other. This provides more choice now as well as the promise of more growth in the future.

When evaluating options, it can be especially important to understand whether the wireless protocol is based on a standard, or truly uses the full standard as written. This can mean the difference between two devices being able to communicate out of the box.

• **Power management** can be a critical issue in integrating wireless capabilities. Because the radio component requires a power source in order to transmit and receive signals, the fixture / power supply manufacturer must find the appropriate way to provide power to that component.

With other devices, such as switches, dimmers and sensors, power is an even more central issue. Truly wireless devices in these categories receive no external power wiring, so the radio must be powered from an internal source. This means either a battery, or harvesting the power from physical or ambient energy.

In either case, the designer of the device must utilize effective power management abilities (such as having the device "sleep" between transmissions) in order to retain power.

- Effective **commissioning** is of the utmost importance when designing a fixture or device for use as part of a wireless network. Different wireless protocols (and vendors) offer a variety of methods for commissioning. Be sure that the method chosen is appropriate for the final customer segment – for example, a method that relies solely on patterns of button presses may not work well for commissioning large commercial buildings or high-bay environments.

- **Antenna placement** is an important design consideration when integrating wireless networking. Wireless protocols have different effective ranges as well as different reactions to various materials. The most common example is the "Faraday cage" effect, where a fully sealed metal enclosure will block radio signals from escaping. Depending on the materials and construction of the fixture, the design may need to incorporate an external antenna.

- Other typical **design considerations** include size and heat rating. Many devices are currently designed for very efficient use of space, so including a wireless radio or module may require an enclosure re-design. And as lighting manufacturers know well, every component must be properly rated for heat exposure.

- Just as important as the hardware considerations are the **firmware development and upgrade** considerations. Namely, who will develop and maintain the firmware; and how will it be upgraded? Many fixture manufacturers will look to third parties to handle much of the software side, and many of the module vendors offer this capability either as a pre-packaged set, or with custom development. The upgrade issue comes down to either an over-the-air upgrade or some form of physical connectivity – another hardware consideration.

- Finally, the **business concerns** listed in the prior section will carry critical weight in determining how wireless is integrated. What is the added cost per device, which SKU(s) will be able to take advantage of this development effort, and what is the engineering cost and time to market?

Daintree Networks Wireless Integration Options

Daintree Networks offers its partners a variety of integration options, either through products or partnerships, to meet the above requirements and needs. All of Daintree's products and the options below use the ZigBee wireless standard, in its open and fully interoperable form, to ensure robust and scalable wireless lighting intelligence.

Daintree's **WA100, WFA100 and related Wireless Adapters** are designed to provide an array of capabilities for options one and tow above (third-party wireless adapter, purchased separately or built in).

- The **WA100** provides on/off/dim capabilities for up to 10 fixtures (dimming) or 15A (on/off), plus sensors. It is plenum rated, and is available with or without an integrated power meter. The WA100 is typically installed at the customer site, either inside individual fixtures or at a junction box to control multiple fixtures.

- The **WFA100** provides on/off/dim capabilities to individual fixtures, with a slim form factor for in-fixture installation. It can be installed at the customer site, or pre-installed by a fixture manufacturer at the point of manufacture. Sensor capability is optional.

Daintree partners with ZigBee module and IC manufacturers who provide standard components for options 4 and 5 above (Integrated Wireless Module or IC). Through these partnerships, Daintree can recommend appropriate components to meet the fixture manufacturer's needs. Daintree also provides detailed firmware guidelines free of charge, to simplify the process of developing firmware for an integrated ZigBee module or radio.

Some module and IC manufacturers have developed reference designs for lighting products, and some provide development tools or services to make integration simpler. Because these products are available off-the-shelf from high-volume manufacturers, and use the established ZigBee standard, component costs and development requirements are typically low.

For those manufacturers looking to pursue option three (custom wireless adapter), Daintree can also provide guidelines and assistance.

About GE Current

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Current's Daintree is a channel-friendly product line with leading strategic and technology partners helping serve its customers globally, with major locations in Silicon Valley, CA, Cleveland, OH, and Melbourne, Australia.

Further information is available at **www.products.currentbyge.com**