

WIRELESS TECHNOLOGY IN LIGHTING

Wireless lighting systems need to be reliable by nature, secure by design, and compatible by scale. To achieve that reality, wireless technology must be understood in a way that eliminates confusion and helps drive alignment.

This learning guide:

- ✓ Introduces key concepts in modern wireless lighting systems
- ✓ Identifies major trends impacting designers, installers, and operators
- ✓ Provides context and considerations for decision makers

Why Does it Matter?

Cost savings, time savings, reliability, and cybersecurity, just to name a few reasons.

Observing trends at the macro level suggests wireless technology will continue to gain market share—and for some product lines, wireless devices are already the default option.

As the scales continue to tip in favor of wireless technology, it is increasingly important to understand basic concepts so that legitimate concerns can be addressed and myths can be dismissed.

 **The goal of this learning guide** is to educate the public and to facilitate conversation between building owners, developers, lighting designers, and the broader lighting supply chain.



Getting Comfortable with Wireless

Whether you are connecting to Bluetooth headphones, sending a text message, or opening a garage door, you are already familiar with the benefits of wireless technologies.

While most of us readily adopt and benefit from wireless technologies in our personal lives, fully embracing wireless solutions in business can be daunting and complicated. Getting up to speed with wireless concepts is the first step in understanding whether wireless technology can work as well for your business as it does for your personal life.

In the parlance of Networked Lighting Controls (NLC), wireless is often a catch-all phrase applied to everything from: wall stations that communicate with load-control devices to wireless gateways that connect individual luminaires to central and remote servers. The catch-all nature of this term coupled with the fast pace of technology development is a key source of confusion in the market.



Remote controls



Wall stations



Sensors



Load controller
(Imagined here inside a fixture)



Gateways



Smart devices

Understanding wireless starts with understanding communication protocols

In **technical jargon**, a communication protocol is a system of rules that allows two or more entities to transmit information. In **plain terms**, a communication protocol is like a specific language that allows two or more people to share and understand information.

This learning guide focuses on the wireless protocols most commonly found in networked lighting systems in the North American market including: **Wi-Fi, Bluetooth Low Energy (BLE), Zigbee, and similar proprietary protocols.**



By providing our computers and smart devices with access to the internet, Wi-Fi has become so ubiquitous in the past two decades that it is now considered a standard feature.

Wi-Fi is a suite of wireless network protocols based on the IEEE 802.11 family of standards, which are commonly used for local area networking of devices and internet access.

Wi-Fi's best feature is that it can transmit very high rates of data. However, Wi-Fi uses significantly more power than low energy protocols. The battery life for most Wi-Fi devices, like your smartphone or laptop, is a few hours.

Wi-Fi typically operates on a hub-and-spoke network design, known as a topology. The Wi-Fi router serves as a central hub and gateway that can be connected to multiple devices.

▶ **Point of Clarification:** Wi-Fi is a specific protocol and shouldn't be used as a catch-all phrase for all wireless protocols.

Bluetooth Low Energy (BLE) and Zigbee are examples of low energy (LE) protocols. As their name implies, LE protocols use such little power that they can reliably operate for years at a time with nothing but inexpensive batteries.



BLE is distinct from classic Bluetooth, but the two protocols can both be supported by one device. BLE is intended to provide considerably reduced power consumption while maintaining a similar communication range as classic Bluetooth.



Zigbee is a popular protocol belonging to the IEEE 802.11.4 family of specifications. Zigbee is well-suited for lower power and low bandwidth applications.

▶ **Point of Clarification:** LE protocols are not frequency-specific, e.g., Wi-Fi and BLE operate at 2.4 GHz

Other protocols addressed



EnOcean is a proprietary protocol that enables energy harvesting and is discussed more on page 6.



DALI is a digital, open-source protocol that enables both wired and wireless solutions and is discussed more on page 9.

Understanding the Market

Because Wi-Fi requires a power source and can transfer high rates of data, it does not compete directly with LE protocols. In fact, to achieve full capabilities, most systems pair Wi-Fi with a preferred LE protocol. By contrast, BLE and Zigbee are direct competitors.

There's no such thing as the perfect frequency.

Sub-1 GHz protocols are low energy and provide high reliability for basic commands.

2.4 GHz is a popular choice, but is crowded and offers limited channels.

5 GHz offers high data transfer rates but has limited range and may require repeaters.



BLE and Zigbee are examples of low energy protocols that operate at 2.4 GHz.



Modern Wi-Fi networks operate on both 2.4 and 5 GHz to optimize performance and reliability.

All wireless protocols in lighting operate within the Industrial Scientific Medical (ISM) frequency band. The ISM frequency band is clustered around 2.4 GHz and represents the RF spectrum range available to the public.

What key performance indicators matter for wireless?



When highlighting the value of their technology, manufacturers often cite key performance indicators (KPIs) such as data transfer rates, signal distance, the number of devices that can be connected, and power consumption. While the reported values speak for themselves, actual performance levels like data throughput and distance can vary significantly. Such levels are dependent on factors such as construction materials and component quality.

Wireless KPIs	BLE	Zigbee	Wi-Fi	Extra Security The “defined user layer” simply means that specific credentials are required to access the system. Think of a teacher entering a PIN on their phone to gain access to the lights.
Data transfer rate	1–2 Mbit/s	250 kbit/s	11 Mbit/s for 2.4 GHz 54 Mbit/s for 5 GHz	
Signal distance (meters, line of site)	10–30	10–20	45 for 2.4 GHz 15 for 5 GHz	
Power consumption	10–500 mW low energy	1–100 mW low energy	~6–20 Watts	
Encryption	AES 128-bit + defined user layer	AES 128-bit	WPA2–256-bit key	



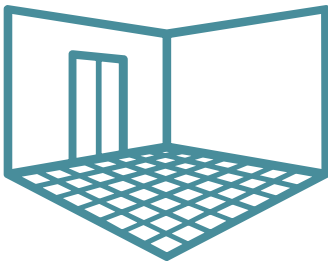
It's a router, it's a hub, it's a firewall... it's the gateway

A gateway is a hardware device that connects two networks with different protocols. It effectively acts as a "gate" between the two networks. In networked lighting systems, gateways are the bridge between LE protocols, Wi-Fi, Application Program Interfaces (APIs), and the broader internet.

Specific manufacturers may use different names, so don't be afraid to ask: "Are you talking about the gateway?"

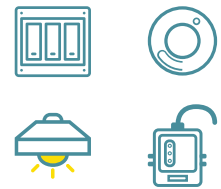
- ▶ **Point of Clarification:** Networked lighting systems have required both LE protocols and Wi-Fi to achieve capabilities beyond simple room-based control. While Wi-Fi is still required for several key features, recent developments with BLE mesh suggest the role of LE protocols will continue to grow.

Wireless in room-based systems



In these systems, wireless sensors, wall stations, and load controllers all use LE protocols such as sub-1 GHz, BLE, or Zigbee to communicate directly.

With the exception of BLE mesh, room-based systems using LE protocols are not networked beyond the individual room.



Lighting devices using
LE protocols

Wireless in whole floor, building, or enterprise systems



For most systems, a gateway device is required to network multiple spaces within a building, and to access key features such as BACnet, energy monitoring, scheduling, and automatic demand response.

Gateway devices connect individual room-based systems using LE protocols—ultimately providing these systems with access to the internet.



BACnet
API



Energy
monitoring



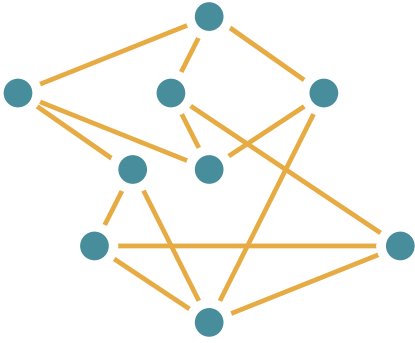
Scheduling



Automatic
demand response

Features commonly
requiring Wi-Fi via a
gateway device

Mesh Networks and more with BLE



Another advantage of LE protocols is their ability to enable mesh networks. In a mesh network, each device can pass information forward to other devices. Compared to traditional wireless topologies, mesh networks are considered robust and resilient.



Mesh networks operating with LE protocols typically offer greater capabilities and easier configuration than networked systems that rely on specific physical gateways, such as an entire building with lights that can only be switched off by a single smartphone.

Systems using BLE mesh networks also allow users to configure the system using app-friendly tools without requiring a gateway device.

Proprietary vs. Open Standard Systems—and the Space Between

Investing in a modern networked lighting system is a lot like investing in new smartphones or other IT-related services.

Whereas computers and smartphones allow users to communicate effectively between devices regardless of brand, **nearly all networked lighting systems operate with proprietary protocols that intentionally limit interoperability in the name of reliability.**

The result is that different lighting systems are unable to work together. Building owners are often forced to choose between one system that comes with compromises or maintain multiple systems for desired control.

Commercially available NLC systems primarily come in two flavors: completely proprietary and proprietary built on open standards.

► **Understanding your options and being able to communicate what's important before the specification process can help you save time and money down the road.**

Proprietary Protocols

Systems operating on completely proprietary protocols have the advantage of working within a very controlled ecosystem and often benefit in terms of reliability and ease of initial setup. The downside of strictly proprietary systems is that users are limited in terms of access to hardware, and are locking themselves into a specific brand for the foreseeable future.

Open-Standard Protocols

Systems operating on fully open standards such as Bluetooth Mesh or DALI represent a growing market segment. Open protocol systems benefit from a broad supply chain which offers a wide range of ancillary products to meet customer needs (e.g., wall stations or sensors). Open systems are also considered some of the safest because the model of transparency ensures everyone is working collaboratively to keep the protocols free from cyber threats.

Backwards Compatible and Future Proof

Backwards compatibility is an important property of a system or product that allows interoperability with an older legacy system. Future proof refers to a system's ability to receive over-the-air updates that can expand capabilities, patch vulnerabilities, and prolong life.

Currently, a majority of lighting systems reside in the middle ground and can be described as **proprietary built on open standards**. These systems add their own special sauce to existing open standard with the hope of achieving the best of both worlds. The downside to proprietary protocols built on open standards is that they are still proprietary.

<p>▶ Not sure which system type?</p> <p>Don't be afraid to ask.</p>	<p>Proprietary</p>  <p>Apple</p>	<p>Proprietary Built on Open Standards</p>  <p>Microsoft Windows or Google Android</p>	<p>Fully Open Standard</p>  <p>Linux</p>
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Walled garden, or closed platform, is used to describe the ecosystem of products created when lighting controls manufacturers partner directly with fixture manufacturers. The arrangement allows manufacturers to expand their market reach with comprehensive solutions for customers. To ensure a high level of reliability and security, applications and communication protocols are restricted.

In **fully proprietary lighting systems**, the entire operating system and all associated hardware is controlled by the manufacturer. End users can do whatever they want, as long as it's strictly within the ecosystem.

Proprietary lighting systems built on open standards offer varying degrees of restrictiveness. While they are still walled, the walls are lower and end users typically gain access to greater product selection.

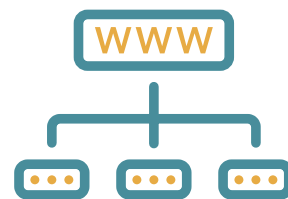


Cybersecurity

Cybersecurity is the practice of defending networked systems and data from malicious attacks. Cybersecurity does not have a one-size-fits-all solution and multiple 3rd party standards exist. In order to determine which security standards will best mitigate risk, end users need to identify and provide lighting designers with the specific criteria that matter.



Networked vs. connected to the internet: It is important to understand that though the system is a network, it does not necessarily have to be on the building IT network or have access to the public internet. It is widely considered best practice for lighting networks to operate as privately firewalled-off intranets.



Remote access: Adding a gateway can allow for remote system access—for monitoring energy consumption or control capabilities—but only if the lighting system gateway is itself bridged to an internet-connected server.

Rely on the experts: Maintaining the highest level of network security, especially when IP devices are connected to the internet, requires specially-trained personnel who can implement the necessary techniques to ensure continued protection.



The Design Lights Consortium's networked lighting controls qualified products list is a great resource to review and compare lighting system capabilities including cybersecurity certificates. Google "DLC NLC QPL" to search the list.

What is Energy Harvesting?

EnOcean is an energy harvesting technology that powers devices through either kinetic energy (the physical act of pushing a button), micro solar, or both.

This technology uses such little power that no battery is required. To achieve this, EnOcean has developed a proprietary protocol available for license.

Recently, both BLE and Zigbee updated their standards to require interoperability with EnOcean devices. This effectively means that BLE and Zigbee lighting systems can offer wireless and battery-free devices that will be compatible upon setup.



Then vs. Now: Highlighting Three Macro Trends that Matter

From Mostly Reliable to Resilient



A fair critique for wireless technologies is that being reliable most of the time isn't nearly close enough. With wired solutions providing nearly perfect reliability, the bar for performance has been set high.

Wireless protocols and the standards that define them are continuously evolving thanks to advances in technology. With creative input from individual manufacturers, modern systems deploy multiple methods to provide rapid communication and resiliency between connection points.

Modern lighting systems deploying BLE mesh create multiple connection points to any specific node, which in effect means every signal is sent (and received) multiple times. A capability known as data resiliency allows devices to store information for nearby devices while they are asleep or offline.

From Who's Who to Hello Old Friend

Past wireless technologies meant that two paired devices would invariably lose connections. They would then have to be manually reintroduced before they could start functioning again.



Modern wireless protocols and the devices they connect are now capable of assigning specific IDs to every device within the network (like an IP address). Embedded logic and sophisticated programming detects nodes that may temporarily drop offline and automatically reroutes messages.

When the node comes back online, it is automatically detected by nearby devices, and its function and role is already known. This is sometimes referred to as self-healing.

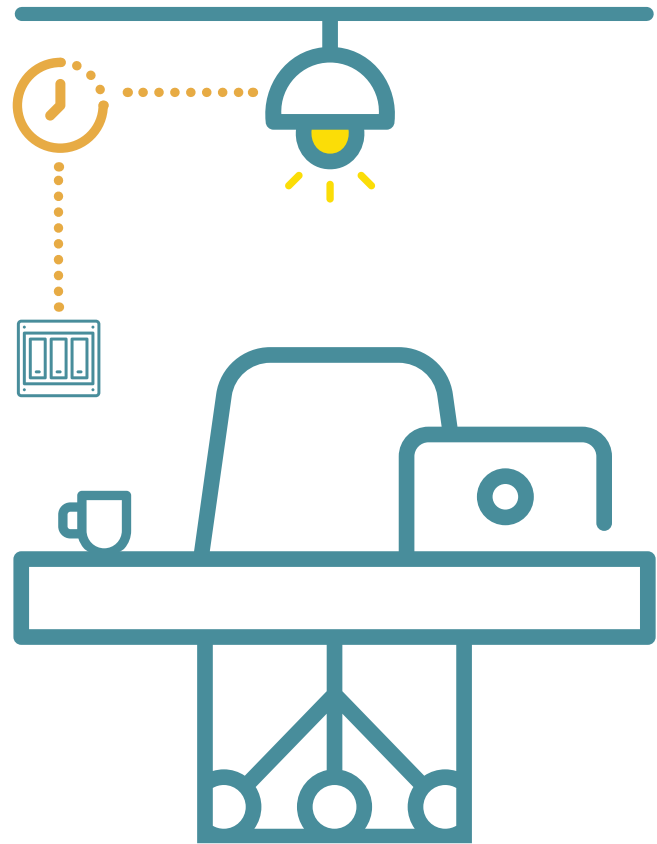
The end result is less time troubleshooting systems and more time forgetting they are wireless at all.

From Latency to Uniformity

Early adopters of mesh networks cited latency between luminaires or zones when wireless scene commands were sent and received. Changing scenes might result in fixtures responding in either a cascading wave or random pattern.

The most recent versions of LE protocol standards have addressed latency with the combination of improved signal speed, clever programming, and flexible topologies. Individual devices (or nodes) are able to detect both the direction and distance of other connected devices and then sync commands to achieve uniform scene transitions.

The end result is that small and large spaces alike can be controlled with a uniformity that provides end users with seamless scene transitions.



Failing to Plan is Planning to...You Know

When lighting systems are specified primarily on cost or contractor familiarity with install, problems can arise down the road that often dwarf the original savings. Getting organized internally around the following issues will empower key stakeholders and help inform the right type of system.



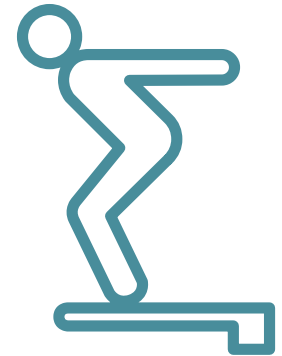
Are you ready for wireless?

It's not unusual for the wired or wireless decision to be determined by a single individual's input during a single meeting.

The ramifications of wired vs. wireless are significant, so businesses thinking about purchasing a new lighting system should proactively align on their needs and potential concerns for manufacturers' reps to address.

Capital planning managers, facility operators, and IT professionals should work together to consider the following questions:

- What *specifically* (if any) are your concerns with wireless?
- Do you anticipate the likelihood of spaces being reconfigured with different lighting zones (i.e., value in future system flexibility)?
- Do you need wireless capabilities beyond room-based systems?
- What is your team's preference for maintaining a system based on wireless protocols (e.g., remote control, app-based device, push 'n connect)?



Cyber What?

Don't let the tail wag the dog! Owners' representatives need to ensure their IT professionals are at the table to document security requirements and system performance expectations before product specification occurs.

IT professionals should consider and document the following questions:

- Should building control networks be physically separate from the corporate LANs?
- What cybersecurity credentials or certificates do you require?
- What levels of user-based security are appropriate for your facility?
- What requirements are in place for other platforms connected to the building management system?



Don't Be Afraid to Ask the Following Questions



Everyone understands the value of comparison shopping, but getting an apples-to-apples comparison with networked lighting systems can be tricky. Potential system owners and facility operators can use the following outline to document their own system needs—and better understand the capabilities of competing products.

- Does this system require a gateway for desired capabilities?
- Does this system offer configuration with an app-based device?
- If the system is based on an open protocol, is it developed on the latest standard?
- Will multiple users be able to access and maintain the system on multiple devices?
- What is the rated battery life for the wireless devices and does the system offer low-battery alerts?
- What capabilities are available remotely and which are limited to onsite?

Wireless DALI (Digital Addressable Lighting Interface)

Developed as a successor to 0-10V systems, DALI provides a digital two-way signal and represents one of the most open standards available to the lighting industry. Similar to the Bluetooth SIG and the Wi-Fi Alliance, the DALI standard is managed by the Digital Illumination Interface Alliance, a consortium of member organizations seeking to expand the ecosystem.

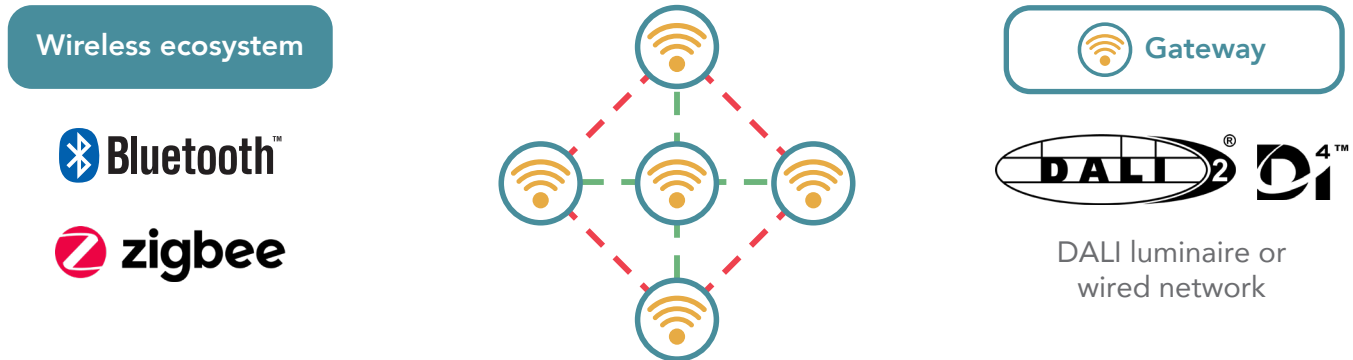
While DALI itself is not a wireless protocol, the latest standard—known as D4i—introduces a native wireless protocol and defines gateways that create interoperability with BLE and Zigbee devices.

In practical terms, products that conform with DALI's latest D4i standard can achieve advanced wireless capabilities via either DALI's in-house, open-source protocol, or via defined gateway settings, which allow for seamless interoperability with BLE or Zigbee-enabled devices like sensors or wall stations.

▶ **Point of Clarification: 0-10V is not a protocol.** Rather, it is the method by which load control devices communicate with drivers via wires in the context of a 0-10V system.

DALI, by contrast, is a protocol because—in addition to providing a digital method for controlling light levels—it also supplies a comprehensive set of guidelines that enable storing and communicating a wide range of luminaire, energy, and diagnostics data in a standardized format.

Achieving interoperability



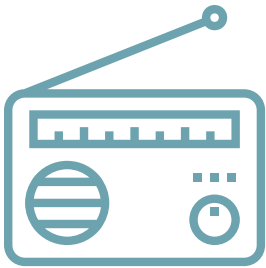
The Road Less Traveled

As discussed earlier, **most lighting systems can be described as either fully proprietary or proprietary built on open standards.** While some manufacturers have chosen to tweak DALI to their unique specifications, others have gone to market leaving the open source protocol completely intact. **If the proprietary companies are like Apple and Microsoft, DALI systems look a lot more like Linux.**

DALI is kind of like Nutella: it started in Europe, but it's not just a European thing

A common refrain from industry vets is that DALI is only big in Europe and, like the metric system, will never really take off in the US. In reality, DALI has always existed in the North American market, but has largely been crowded out by big market actors seeking to push proprietary solutions that bind customers to their products.

With markets shifting in response to demand for IoT, flexibility, and greater product selection, DALI is starting to stand out again. Recently, several major manufacturers sought to create price parity between DALI drivers and the 0-10V controllers to increase competition and support the platform.



Not Your Grandpa's Radio

For all the talk about wireless protocols, it's reasonable to wonder where all these little radios are located and what they look like.

Wireless communication is made possible through the use of transceiver radios that enable two-way RF communication between devices using predefined settings.

Wireless radios are built to specific standards defined by organizations like the Bluetooth Special Interest Group or the IEEE's 802.11.4 committee.

Modern RF radios exist as tiny microchips that can be purchased by product developers as standalone components. Dominant wireless standards organizations like the Bluetooth SIG, the Zigbee Alliance, and the Wi-Fi Alliance have effectively created mass markets which simultaneously provide:



- Certainty for manufacturers looking to mass produce chips.
- A known and reliable platform for developers to build in.
- A trusted product ecosystem where ostensibly, consumers have confidence that compatible parts and pieces will operate in harmony.

The massive markets created as a result drive more manufacturers and product developers to sign up, and the pie continues to grow.

With wireless showing no signs of slowing down, chip manufacturers have started embedding multiple radios into single chips. (e.g., Wi-Fi, BLE, and Zigbee).

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