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Illuminating
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LIGHTING PRACTICE:
IOT CONNECTED LIGHTING
AN AMERICAN NATIONAL STANDARD

Approved American National Standard

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Preface

The flywheel of continuous technological and economic improvement is now fed by a nearly perpetual stream of data made available from a ubiquitous array of both physical sources (devices) and virtual sources. “Data is the new currency” that nourishes and sustains the burgeoning big-data marketplace.[1] Given the ubiquity of lighting and lighting control assets across the built environment, lighting professionals within the intersecting domains of design, distribution, manufacturing, and implementation are now faced with challenges and opportunities associated with the generation, transmission, and synthesis of occupant and building data into actionable insights capable of improving operational and personal outcomes for building owners and occupants.

As defined in **Section 7.0 Glossary**, the internet of things (IoT) is a system of physical computing devices, such as sensors and actuators, capable of communicating data via a network and which can be used to perform logic-based actions (e.g., make adjustments, send alerts) and/or to present data for the purpose of analysis. For example, industrial sensors that collect data on machine vibration and send that data to the cloud are a part of the internet of things, as are smart watches that can monitor a person’s heart rate during exercise and send that information to an app on the user’s phone.

IoT applications offer many distinct advantages to stakeholders, such as building owners, operators, and occupants. However, IoT has not changed the inherent goals of a building operator—to improve operational efficiency and increase occupant comfort and productivity. Instead, the IoT helps building operators better understand how their space is being used, in both historic and real-time applications, to more effectively deliver on those core goals. The main goal or outcome of IoT systems is to facilitate connectivity between devices, building systems, and humans. These connections enable meaningful interactions and interoperability (e.g., personal control and automation), as well as enabling the collection, transmission, and synthesis of device or system data to convey relevant insights to building owners (e.g., building energy usage, floor space utilization) and occupants (e.g., personal control, wayfinding).

History

The term “Internet of things” was officially coined in 1999 by Kevin Ashton, who during his time at Procter & Gamble as a brand manager was interested in linking new radio-frequency identification (RFID) technology to be used within P&G’s supply chain to the then newly emerging Internet. While the term *internet of things* (IoT) is relatively new within the lighting community, its roots are closely tied to the evolution of communication systems, which stem back to the invention of the electromagnetic telegraph, by Russian inventor Baron Pavel Shilling von Canstatt in Russia in 1832, and the first public telegraph message, by American inventor Samuel Morse in 1844.

Notable historical milestones:

- In a 1926 interview,[2] Nikola Tesla remarked, “When wireless is perfectly applied, the whole earth will be converted into a huge brain, which in fact it is, all things being particles of a real and rhythmic whole … and the instruments through which we shall be able to do this will be amazingly simple compared with our present telephone.”
- *Machine learning:* From Alan Touring’s 1950 Computing Machinery and Intelligence article[3] in the Oxford journal *Mind*: "It can also be maintained that it is best to provide the machine with the best sense organs that money can buy, and then teach it to understand and speak English. This process could follow the normal teaching of a child."
- *Smart cities:* From Marshall McLuhan’s 1964 work titled Understanding Media: the extensions of man[4]: "... by means of electric media, we set up a dynamic by which all previous technologies—including cities—will be translated into information systems.”
- *Intelligent devices:* In 1966, German computer science pioneer Karl Steinbuch said, "In a few decades’ time, computers will be interwoven into almost every industrial product."

More-recent roots stem from the 1970s, under the term *pervasive computing*. In 1982, graduate students in Carnegie Mellon's Computer Science Department connected a vending machine to the internet to enable checking stock and the internal temperature. However, it was not until the 2010s that the concept of IoT began to grow in popularity. More recent and notable historical activities are LG's first internet-connected refrigerator, introduced in 2000, and David Rose's Ambient Orb introduction in 2002, which was designed to provide personalized visual feedback from a variety of sources, such as the weather or stock portfolios.

According to a Cisco Internet Business Solutions Group (IBSG) white paper,[5] the internet of things was born between 2008 and 2009, at the point when more "things or objects" were connected to the internet than people were. Since this time, countless connected IoT devices have been implemented in nearly every industry and built environment to generate, collect, and make use of device, environmental, and occupant-based data. This has led to new use cases, applications, and opportunities, of which many fall within the domain of lighting professionals.

IoT Emergence With Lighting (or, Why Lighting?)

Why has the emergence of IoT taken off so strongly within the lighting industry? It could be the industry's readiness for change, as evidenced by the solid-state lighting (SSL) revolution, and propensity for constant innovation. It could be the unique vantage point lighting professionals hold at the design table with owners, operators, manufacturers, and installers. But beyond these, it should be recognized that the emergence of IoT within the lighting industry has also been driven by the inherent nature of lighting. Four particular and inherent characteristics drive this alignment between lighting infrastructure and an IoT infrastructure.

- *Distributed:* Due to the need for electric lighting across almost all space types (both indoor and outdoor), luminaires are widely distributed and organized across the built environment and therefore serve as the ideal vehicle for IoT components, which are also distributed.
- *Electrified:* Since all electric luminaires require a source of power, connected power is then available to the IoT devices as well. With the advent of power over Ethernet (PoE)-enabled luminaires, the power source and network connectivity are even further integrated within a single medium.
- *Elevated:* Given that luminaires are commonly elevated high in a given space to achieve the design intent, this elevated location is ideal for many IoT devices, which need to be free from obstruction, safe from tampering, and within purview of the space below (e.g., presence detection). Such elevated locations also assist in reducing interference in cases where connectivity is achieved via wireless means (e.g., connected city streetlights).
- *Discreet:* People are accustomed to luminaires serving the spaces they occupy, as they contribute to the aesthetics of the space. By integrating IoT capabilities into the luminaires, the overall aesthetic can be maintained. This not only serves a visual purpose, but can provide other benefits as well, such as being intentionally incognito (e.g., for security surveillance).

1.0 Introduction and Scope

1.1 Introduction

Businesses and organizations are in constant pursuit of effective technology solutions to address their strategic, tactical, and operational effectiveness.[6] As such, many organizations have become increasingly interested in exploring the use of intelligent systems, such as smart lighting solutions, to address this opportunity within the built environment. The convergence of the physical and virtual domains, such that physical devices that occupy the built environment now exist in a virtual, digital environment, is referred to as the *internet of things* (IoT).

The lighting industry, like many other industries, continues to evolve in an attempt to address the ever-changing needs of its stakeholders. Lighting professionals are now faced with decisions that extend beyond the central issues of lighting quality and energy efficiency, and into the realm of big data and business intelligence (BI). Terms such as *smart lighting*, *connected lighting*, and the *internet of things* (IoT) have become more prevalent within the overall lighting vernacular. However, in due time these terms will no longer have the distinctive or unfamiliar undertone associated with new or advanced technology, as the future of lighting may in fact be closely interwoven with that of IoT. In the future, smart, connected, or IoT lighting will likely just be referred to as lighting. Luminaires are both ubiquitous and energized, two characteristics that make them an ideal choice to deploy with fully integrated assets, such as intelligent sensors. Where appropriately specified and implemented, the addition of intelligent sensors, or related devices, can extend the value proposition of lighting beyond the realm of efficiency and automation by enabling previously unavailable and statistically relevant insights into the operation, performance, and utilization of the built environment. Similarly, incorporating other assets such as wireless transceivers alongside or within luminaires may have secondary or tertiary use cases that may enable additional services and applications for both owners and occupants of a space.

In the spirit of this document, *smart lighting* is a loosely defined term used to describe lighting and control equipment that is implemented in such a way as to provide secondary benefits, such as the communication and utilization of devices or operational data to enable actionable insights, interoperability, or value-added applications such as real-time location services and asset tracking.

In the context of ambient lighting applications, connected lighting is most often embodied by a network of sensors, luminaires, and controls that are installed in buildings to capture, transmit, store, and manage information about the spaces they occupy. Connected lighting can be used to optimize lighting and share data, such as occupancy and energy data, with other building systems to enable specific IoT strategies for both building occupants (e.g., personalized space control) and building owners (e.g., floor space optimization).

Key components of an IoT ecosystem include physical objects, device data, and a networked infrastructure (refer to **Figure 1-1**). The IoT enables the synthesis of device data into meaningful insights capable of both

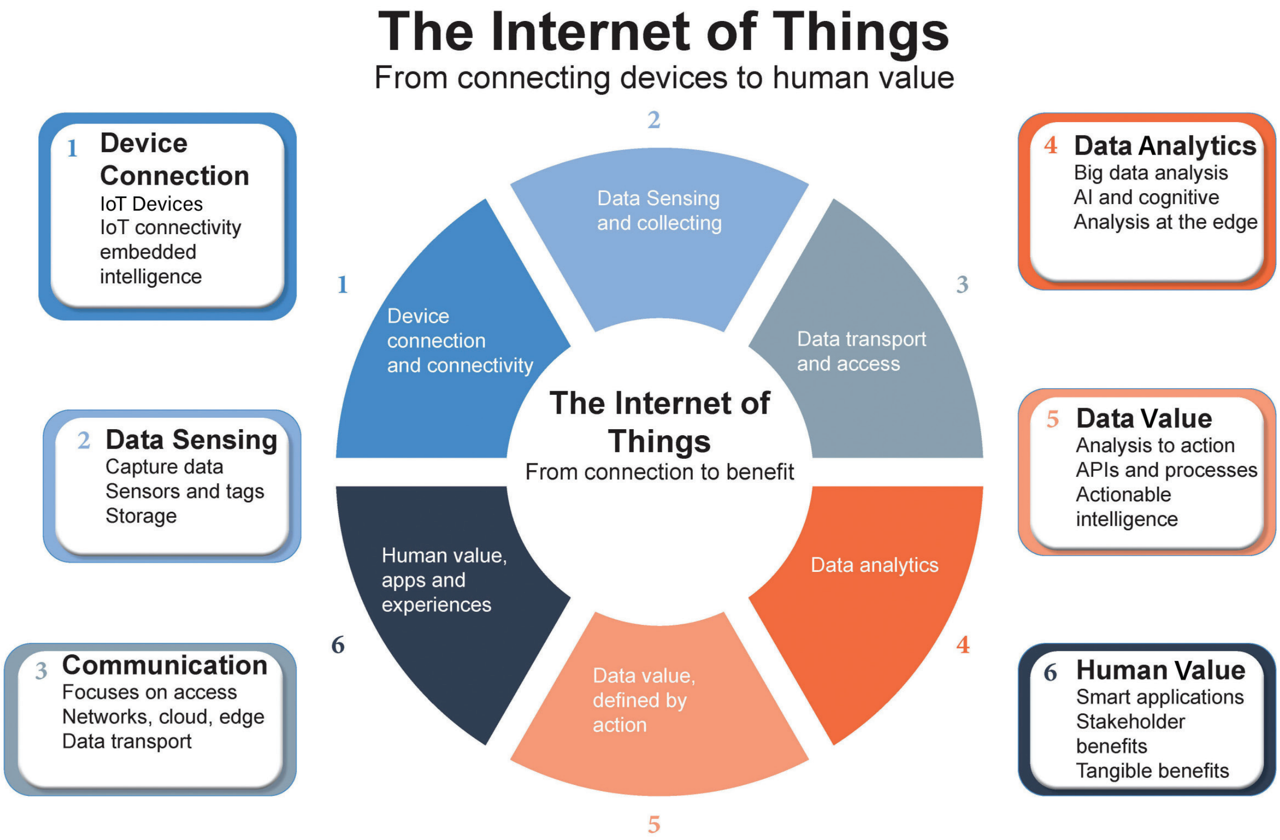

Figure 1-1. An overview of the internet of things (IoT). (Image courtesy of Tec Studio)

informing stakeholders and producing more-favorable outcomes. IoT devices and systems are those that are often designed to communicate with each other, across a purpose-built network (e.g., Bluetooth Mesh, Zigbee) or a traditional building network (LAN) or internet (WAN). Ideally, an IoT system is greater than the sum of its parts. As such, IoT devices are often not complete solutions in themselves but rather components of diverse systems, such as those offered by adjacent industries, that function interdependently as an IoT ecosystem. Examples of adjacent industries include security and access control, indoor environmental (HVAC) controls, building power management, telephony, and audiovisual systems.

1.2 Purpose and Target Audience

The purpose of this document is to serve as a design guide and to provide lighting professionals with the necessary information to consider and evaluate potential connected lighting and IoT solutions and applications. While the body of work represented within this text is meant to explore the most common and emerging commercial connected lighting solutions from the perspective of the lighting professional, the rapid pace of change within the lighting industry and available differentiation among partners and/or suppliers will likely require readers to conduct more-specific or supplemental research for a given application.

The profession and practice of lighting are shifting, entering an era where a greater number of seemingly disparate devices and systems are becoming increasingly more active in the process of integrating and digitizing the modern world. This new era is exciting but is not without consequence. For many connected lighting systems, data modeling and acquisition, management, analysis, and conveyance are central concepts that need to be explored but may fall outside the reasonable scope of most lighting professionals. In addition, terms such as *data privacy* and *cybersecurity* are increasingly becoming more-important aspects of connected lighting systems that demand consideration and are therefore introduced in this document.

1.3 Scope

The focus of this document is on specific solutions and related outcomes rather than simply an exhaustive list of potential technologies. Therefore, specific technologies have been referenced but only to provide contextual support or necessary background to aid in the comprehension and increased competency of a given solution. In this context, specific interest is paid to aspects such as cybersecurity, data privacy, and system maintenance. New terms have also been introduced, such as those related to the design, development, implementation, and maintenance stages of connected lighting solutions, which often have software-related dependencies. While these terms may seem unfamiliar to some lighting professionals, they are a necessary addition to the lighting vernacular to support the goals of this document.

2.0 IoT Applications

For the purposes of this section, the word *application* is being used to describe the action of putting something into operation and should not be confused with project market sectors. The use of IoT-connected lighting functionality can be built into almost any project type. Determining the need for a connected lighting system should be evaluated through thoughtful consideration of the design and the operational and financial objectives articulated by building owners, operators, and occupants. As such, the inclusion of several stakeholder groups is necessary throughout the project lifecycle. There may be additional upfront and operational costs compared to when traditional systems are installed; these therefore may need to be identified and considered prior to installation.

The use of a connected lighting system may allow building owners to realize a reasonable level of energy and maintenance cost savings, compared to spaces designed with conventional lighting technology. However, it should be mentioned that lighting, as a percentage of overall building energy usage, has declined precipitously as a result of extensive adoption of light-emitting diodes (LEDs) as lighting sources. As a result, less energy savings from lighting may be possible when controlling inherently efficient lighting products. Building owners have begun to investigate secondary