SILVAIR

Information-centric networking – a revolutionary approach to wireless lighting control

White paper

October 2018

Table of Contents

Abstract

The last decade proved how challenging the lighting environment is for wireless communication technologies. Connected lighting seems to be stuck somewhere between the "innovators" and "early adopters" stages of the technology adoption curve. The fact that even the most proven wireless solutions were unable to provide wire-like reliability, simplicity and commercial-grade scalability shows one thing. A radical change is needed in how we approach the fundamentals of connected lighting.

Information-centric networking (ICN) is a revolutionary concept developed to address the challenges relating to the exponential growth of data traffic across the Internet. But its major paradigms can be applied to other networking technologies, including those underlying wireless lighting controls. Such an approach produces indisputable benefits, including streamlined data exchange process and drastically improved scalability. This white paper explains what ICN means for connected lighting and how it can be implemented in the lighting environment. It also describes how the Bluetooth mesh specification embraces the information-centric communication model to solve the three pain points of today's wireless lighting control systems: simplicity, scalability and reliability.

Introduction

Over the last couple of years, we have seen a number of wireless solutions emerge on the market, promising to revolutionize a decades-long lighting control paradigm. Indeed, the concept of connected lighting has an enormous potential, from helping us address global sustainability needs to making our working environments healthier and more comfortable. In professional applications, wireless lighting controls promise energy savings, design flexibility, nondisruptive retrofitting and multiple value-added services on top of it all. Considering how much value connected lighting could generate on a global scale, we could expect that things would progress fairly quick. But it turns out that the road from concept to implementation is surprisingly long. It's 2018 and wireless controls still seem to be a thing of the future. There are plenty of promises but very few use cases. Multiple products but no agreed standards. And more importantly - still no answers to a number of major challenges.

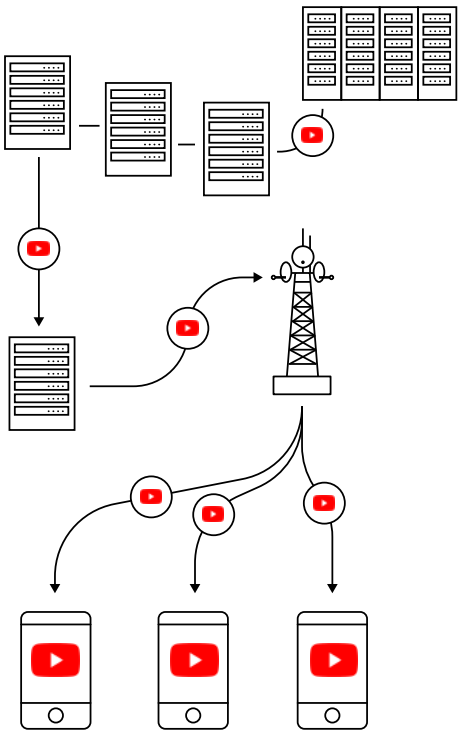
What is holding us back?

A number of factors contribute to the state of connected lighting a.d. 2018. Some of them are known very well. Technological fragmentation and the lack of interoperability have been discussed multiple times over the recent years. Is there any progress in this regard? It's disappointing, to say the least. We should not expect miracles, though. Both these issues are not easy to deal with. This is not something that can be addressed by a single company or even a group of companies. Industry associations focused on connected lighting are important, but their growing number can paradoxically make it even harder to address such problems. So how can you reduce fragmentation and increase interoperability in a fledgling yet promising sector? What can be done to address such market-wide, business-related challenges that keep preventing widespread adoption of connected lighting in professional applications? In the end, it all goes down to technological issues. Both market fragmentation and the lack of interoperability result from the fact that throughout all these years, we didn't witness a wireless control solution that would truly stand out from the rest. There has been no champion; no wireless king that would be able to provide what we expect from smart lighting in the first place – flawless performance. Wire-like reliability. With wired systems, the industry has learned how to tackle the most difficult, sophisticated installations. With wireless systems, we've barely touched the surface. Throughout the short history of connected lighting, no matter what solution you had chosen, you would eventually hit a wall. That wall would usually be the scale. Or industry-grade reliability. How could that be if there is so much value awaiting in the smart lighting segment? Why couldn't we make wireless systems just do their job in the golden age of technology and computer science?

Lessons learned

Perhaps 2018 is the high time to admit that we did it wrong. That certain ideas were doomed to fail. Over and over again, we've seen the connected lighting concept being implemented using the approach known from classic IT networks. This direction seemed natural, but connected lighting turned out to be a huge challenge. It requires low-power, low-bandwidth wireless technologies to deliver robust performance and fully synchronous operation in networks that often scale up to thousands of nodes. With all the conflicting requirements of the connected lighting environment, communication technologies based on traditional IT paradigms were simply unable to deliver wire-like reliability and responsiveness in commercial-scale installations. To learn why - and to find out what can be done about it - we'll have to take a look at a broader picture. Many lessons can be learned from the biggest computer network known to humankind, the Internet.

Networking technologies we commonly use today are based on a host-centric paradigm. Perpetual connectivity, the so-called end-to-end principle and the client-server model for data exchange have become a design framework in computer networking. This is how the entire Internet infrastructure is organized. But the concept of this architecture was designed decades ago, and a lot has changed since then. With the rapid advancements in such fields as mobile technologies, video streaming or cloud computing, the traffic volume is increasing at a rate higher than ever before. And today's Internet is an enormous clutter of never-ending communication loops, redirecions, repetitions and, ultimately, inefficiencies. Think about a viral video stored on a server somewhere in the U.S. Each time someone wants to view that video, data needs to be pushed all the way to his or her computing device.



‹ Figure 1.
A long journey between the content source and the user's device in a host-centric infrastructure of today's Internet

This is a very physical process and as part of it, data often needs to travel literally halfway around the world. We've learned how to effectively transfer data over huge distances, but the rapidly growing scale of data-heavy online requests is becoming a problem. To address this problem, IT scientists have come up with a concept that solves multiple issues relating not only to the Internet, but also to other modern networking technologies. Connected lighting happens to be one of them.

Enter information-centric networking

Information-centric networking (ICN) is a concept developed under the Internet Research Task Force (IRTF)[1], a body focused on long-term research related to the evolution of the Internet. It is an approach to evolve the Internet infrastructure and support its dynamic growth by introducing uniquely named data as a core Internet principle. Moving away from a host-centric paradigm, ICN doesn't care about senders, recipients, addresses. Instead, named information is its focal point, making data independent from location, application and storage[2].

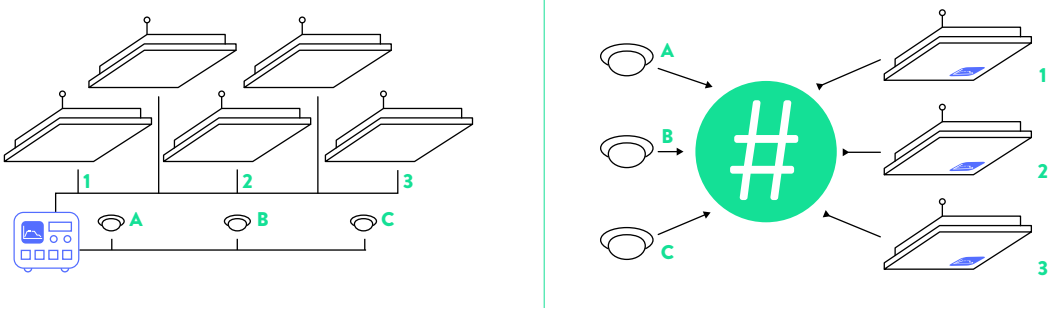
The key paradigms underlying the ICN concept include decentralized architecture, multicast communications and publish-subscribe data exchange model. Designed to address the multitude of redirections and repetitions haunting the Internet today, ICN effectively solves the problem of heavy data traffic being transferred over the same route over and over again. Instead of requesting data transfer from a host server located somewhere in the world, users' devices can access it from the nearest location where this data can be found. So if you're watching that Superbowl game on your smartphone, your neighbor who happens to be doing exactly the same thing could give you a helping hand, while at the same time reducing redundant Internet traffic. The ICN concept effectively removes data bottlenecks across the network and eliminates points of failure by enabling information to be independent from location. This significantly increases the efficiency of the data exchange process, while making the network more scalable, reliable and efficient.

Of course, the Internet is an enormous and complicated space, so it will take years before we witness the ICN architecture fully deployed there. The concept is still under development and we're yet to see what the transition towards the information-centric model will exactly look like. But its core paradigms can be applied to smaller-scale environments today. How do they apply to wireless lighting control systems?

Information-centric lighting networks

The host-centric paradigm is the approach that has been used in all connected lighting solutions so far. And it didn't prove efficient enough. With bottlenecks typical for gateway-dependant networks, low-power wireless technologies with limited throughput faced similar barriers that the Internet is about to face as it continues its exponential growth - scale of the network and reliability of data delivery. And similarly as in the case of the Internet, these challenges can be addressed by putting information at the center.

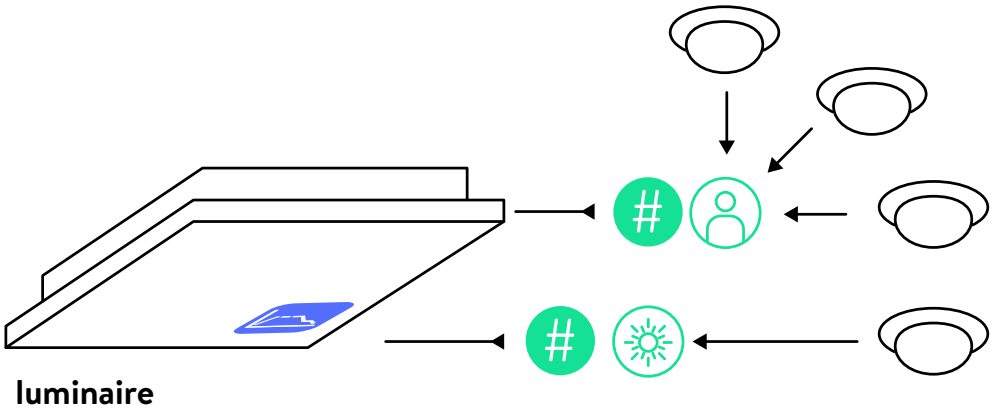
The figure below compares how information is distributed in a typical wireless lighting control network and in a wireless lighting control network utilizing the ICN concept.



‹ Figure 2.
A host-centric lighting control system versus an information-centric lighting control system – logic and architecture

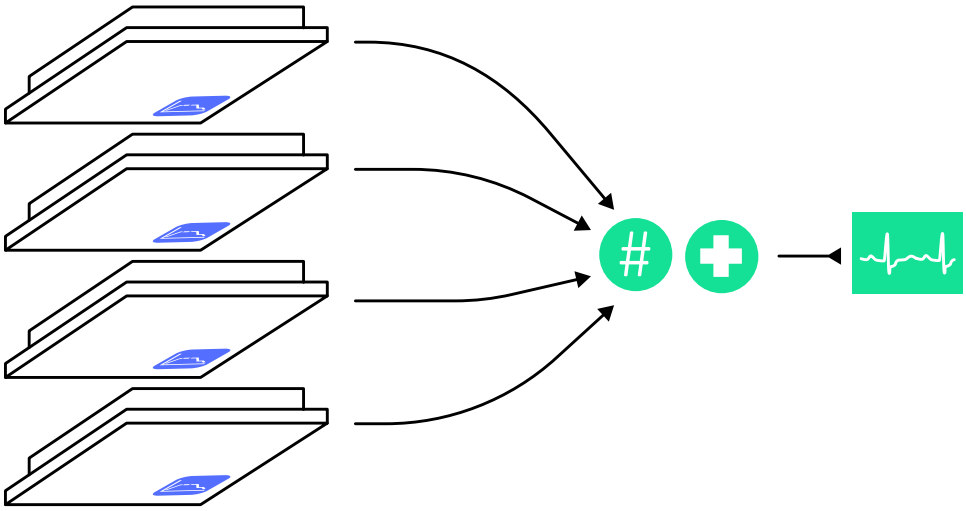
In a host-centric smart lighting network shown on the left, all data is sent to a controller and back. The controller not only becomes a single point of failure (once it fails, the entire network goes down), but also generates bottlenecks that affect the packet delivery rate and, ultimately, the throughput of the network. Just like in today's Internet, data keeps traveling between individual nodes over and over again. Addresses of individual devices are necessary to deliver any piece of information to a desired recipient, so sensors keep pushing information to the controller and the controller then pushes the commands back to each of the associated fixtures, multiplying the traffic volume. In large-scale installations, this communication becomes quite a mess. The efficiency of such network is very low, which is a serious issue for lighting applications where instant responsiveness is taken for granted. Heavy traffic is not what low-power wireless technologies are built to deal with, so they struggle to reliably and efficiently deliver lighting control messages under such circumstances. In a host-centric network, communication between individual nodes is similar to email communication we all use. To say something to a specific person, you need to type his or her email address, compose a message and click send. There is nothing wrong about emails, but sending an "off" command to a ceiling with 50 fixtures is like sending 50 separate emails. Not the most efficient way of communication. Plus, you need to precisely know the 50 addresses. And what if some of them have changed?

The way an information-centric network works resembles, in contrast, Twitter communication - hence the hashtag on the right part of the figure above. Addresses are assigned to information, not to specific devices. Luminaires subscribe to these addresses so that they can respond to relevant messages. Other devices (sensors, switches) publish to these addresses, distributing lighting control commands among all interested parties at the same time. So if we get back to our example with a 50-fixture ceiling, in ICN you don't need to send 50 separate emails. You just publish your content to a relevant hashtag. And all your buddies who have subscribed to that hashtag will immediately see it. So instead of sending 50 "off" commands to all the luminaires in the room, you basically need to publish only one message - all luminaires that are supposed to respond will do it. This is the essence of information-centric networking. Let's take a look at more examples.



‹ **Figure 3.**
Sensors publish data to #OccupancyStatus and #AmbientLightLevel addresses, while luminaires subscribe to these addresses and respond to obtained information

What exactly this “named information” is in the case of lighting control networks? As shown in the figure above, this could be the occupancy status of a particular room. Since ICN assigns addresses to information, this occupancy status is going to have its unique address. The ambient light level in that room will have an address, too. And it doesn’t matter how many sensors contribute to that. Relevant sensors will publish information to these addresses, while luminaires that are subscribed to them will be able to respond to occupancy or ambient light level data from sensors. In addition to streamlining the communication process, such an approach solves such issues as device replacement. If a luminaire requires replacement, the new one only needs to be re-subscribed the same way as the previous one. There is no need to change anything in the configuration of sensors interacting with the replaced luminaire.



‹ **Figure 4.**
Luminaires publishing their operational data to #HealthStatus address

But as shown in the figure above, the address can be assigned also to e.g. the health status of luminaires, so that they can publish their operational data there. This way, administrators can easily access all such data in one place, gaining a comprehensive insight into the entire network.

In addition to being more reliable and scalable, a wireless lighting control system utilizing the publish-subscribe paradigm is also easier to handle. It consists of simple, uncluttered relationships between groups of devices, enabling easier management, maintenance and - if the lighting needs change in a given space - also reconfiguration. To be fully in line with the ICN concept, such network also needs to be decentralized. This means no gateway devices and no control boxes that could constitute single points of failure. Therefore, the logic configuration needs to be dispersed and not condensed within a single device.

All this is quite an impressive set of requirements. To fully realize the ICN approach, a wireless technology needs to move away from networking paradigms of the past century. The information-centric approach is extremely powerful, but it does constitute a challenge in itself. It is just an entirely new quality, full of revolutionary concepts. How to implement them in the lighting environment? Thanks to the recent developments in the wireless industry, this could be easier than one might suspect.

Bluetooth mesh: ICN lighting systems are here

The Bluetooth mesh standard adopted last year is a wireless technology based on the ICN principles. The previous versions of Bluetooth gained global recognition as reliable solutions for the applications they were intended for. But Bluetooth mesh is very different. It implements all of the major paradigms of information-centric networking in order to enable simplicity, scalability and reliability - the three pain points of wireless lighting control systems. First qualified products are now available, with multiple others on their way to the market. What is particularly important, the Mesh Model Specification - one of the three specifications defining the Bluetooth mesh standard - covers all aspects of lighting control and sensing, providing a complete foundation for building robust and scalable lighting control systems.

Bluetooth mesh achieves unprecedented scalability by combining the above mentioned ICN paradigms with unique mechanisms increasing the efficiency of radio communication. First of all, it introduces a fully decentralized architecture with no bottlenecks or single points of failure. Being natively supported by virtually all personal computing devices, it enables smartphones and tablets to communicate directly with network nodes, with no gateway in-between. It also doesn't require central controllers, since it puts controllers into each luminaire. With such a dispersed logic configuration and multi-path packet delivery, Bluetooth mesh networks are exceptionally resilient. Bluetooth mesh networking also supports multicast communication and implements the Twitter-like publish/subscribe paradigm described above, putting information at the very center and effectively streamlining communication across the network.

These innovative communication concepts, coupled with efficient wireless transfer capabilities of the Bluetooth Low Energy radio (ultra-short messages, high spectral efficiency and high data transfer rate) is what makes Bluetooth mesh networks so robust and scalable. In addition to its impressive scalability, Bluetooth mesh provides additional measures that help confine heavy network traffic in extremely dense, large-scale commercial implementations. One of them is the concept of subnets. With a single mesh network capable of accommodating more than 4,000 subnets, Bluetooth

mesh should be able to cover any building automation system we could possibly imagine today. Furthermore, Bluetooth mesh can use three different frequencies, which means that available raw radio resources are significantly larger than in the case of protocols operating on a single frequency.

Bluetooth mesh also has solutions for the typical challenges relating to the commissioning of connected lighting systems. Since the Bluetooth radio can be found in any smartphone/tablet on the market, such devices can be used as network provisioners as long as a relevant app has been installed that reliably and securely supports all the required processes. What's important, from the perspective of both network formation and other stages of commissioning, no gateway is needed to connect with individual nodes and set up the entire mesh network. Bluetooth is the only radio technology that allows for forming the network without touching the building's core IT infrastructure. It doesn't require gateways or Internet connection, so there is no need to obtain any formal agreements from the IT department - a process that can literally take months in the case of more sensitive buildings, such as banks or hospitals. When it comes to device identification and mapping, communication with no gateway in-between also generates significant advantages. Since a smartphone can connect with any other node directly, Bluetooth's RSSI capability (Received Signal Strength Indication) effectively solves the problem of device identification. Simply put, when your smartphone is communicating with a particular network node, it can tell how far this node is. In practice, a smartphone app can use the RSSI filter to narrow down the list of displayed luminaires and sensors to those that are located in your immediate vicinity.

Last but not least, Bluetooth mesh addresses the problem of interoperability mentioned in one of the first paragraphs. With its fully defined application layer and rigid qualification procedure, this new wireless standard opens up a global lighting control ecosystem where products from different vendors can work with each other out of the box. Driven by more than 34,000 members, the Bluetooth Special Interest Group has 20 years of experience in developing globally successful and interoperable wireless standards. Its latest invention, Bluetooth mesh networking, introduces so many revolutionary concepts to wireless lighting control that its adoption truly marks the beginning of a new era for connected lighting. The era of information-centric lighting networks that finally can match wired systems in terms of reliability and scalability.

[1] Official website of the Internet Research Task Force (http://irtf.org/)
[2] Official website of the Information-Centric Networking Research Group (http://irtf.org/icnrg)

About us

Silvair provides complete and flexible lighting control solutions based on Bluetooth mesh networking technology. Component manufacturers can easily integrate them into a variety of products, becoming part of a globally interoperable ecosystem. In addition, our intelligent lighting platform includes a set of dedicated tools for commissioning and managing connected lighting systems in commercial spaces.

We give our partners a head start with a ready-to-use wireless technology, the shortest time to market, and guaranteed compliance with the Bluetooth mesh specification.

For more information visit www.silvair.com

If you have any questions, contact us at:
business@silvair.com

For media inquiries, please contact:
media@silvair.com

Our offices:

Europe
Jasnogorska 44
31-358 Krakow
POLAND

North America
717 Market Street, Suite 100
San Francisco, CA 94103
USA

SILVAIR