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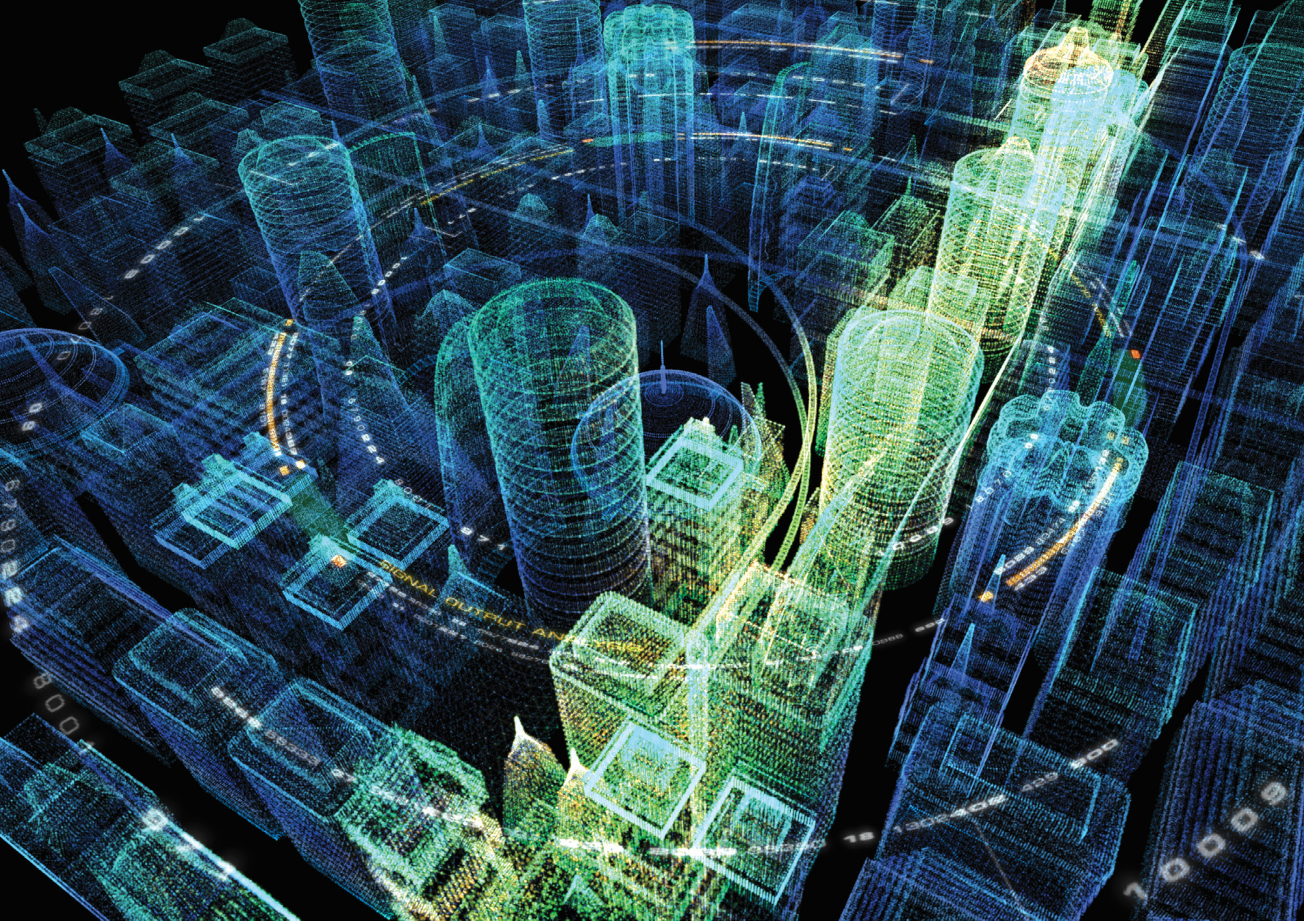

DIGITAL BUILDING SOLUTIONS—THE FUTURE OF BUILDING TECHNOLOGY

By Keith Parker

Explore the opportunities and the technical implementation of digital building solutions. Buildings typically run with high costs mainly incurred in day-to-day operations, management, and maintenance. Buildings are responsible for a high percentage of greenhouse gas emissions and can affect the health and well-being of occupants in poor indoor environmental quality (IEQ) living and working spaces. High performance buildings are realized through an integrated approach toward achieving energy efficiency, limited environmental impact, and the lowest life cycle costs possible. The advent of new technology in smart buildings and the connection between various hardware and software has allowed resources to be controlled and processes to be automated.

The implementation of intelligent solutions is one way to ensure that the building performs optimally over its entire life cycle. The holistic networking of systems in commercial and residential buildings enables them to be controlled more energy efficiently, sustainably, and cost-effectively.

THE EVOLUTION OF DIGITAL BUILDINGS

A smart (intelligent) building refers to any structure using integrated processes, smart engineering, or design to self-regulate its environment and operations. A few decades ago, smart buildings had building management systems (BMS) comprising of disconnected subsystems or silos that were automated at the level of individual functioning. Today, building owners have access to large amounts of information that they can use to make intelligent decisions that enhance building performance.

Underpinning important subjects, such as sustainability, health, and security, a higher investment has been observed in technology and platforms to deliver the seamless management of high data centric outcomes.

It is advised to consult ANSI/BICSI-007-2020, *Information Communication Technology Design and Implementation Practices for Intelligent Buildings and Premises*. This comprehensive standard covers much of what is discussed in this article and compiles IEEE and other global standards.

POWER OVER ETHERNET

Power over Ethernet (PoE) is a technology for delivering direct current (DC) power to devices over copper Ethernet cabling. Moreover, PoE enables one single cable to provide both electrical power and data connection to many different devices along balanced twisted-pair Ethernet cables. It makes it possible to supply power to devices, such as wireless access points (WAPs), IP cameras, voice over IP (VoIP) phones, LED lighting, emergency lighting, Internet of Things (IoT) gateways, and well-being sensors. The PoE is the backbone technology to enable digital building solutions to come to life. An intelligent infrastructure facilitates data collection and analysis, enabling digital services and applications to turn data into actionable insights.

The PoE standard was first established by the IEEE in 2003 (IEEE 802.3af), followed by the IEEE 802.3at standard in 2009, and the IEEE 802.3bt standard in the third quarter of 2018. The latest standard, called Four-Pair-PoE, has evolved the technology's capabilities to the point where BICSI designers, installers, and consultants are now able to find entirely new use cases adapted to the growing needs of various equipment. The higher power levels make several new applications possible. Initially designed for a maximum of 15 Watts (W), PoE can now deliver up to 90 W. See Figure 1 for the PoE standardization roadmap.

	2003	2009	2011	2018
	15W PoE	30W PoE+	60W UPoE	90W UPoE+
	VOIP Phones	**802.1AC Access Points**	**UPoE Powered Compact Switches**	**USB-C Devices or Passthrough UPoE**
Property	**802.3af** Type 1 PoE	**802.3at** Type 2 PoE+	**802.3bt** Type 3 UPoE	**802.3bt** Type 4 UPoE+
Power Available at PD (powered device)	12,95W	25,50W	51W	71W
Maximum power delivered by PSE (Power Sourcing Equipment)	15,40W	30W	60W	90W

FIGURE 1: PoE standardization roadmap.

THE PoE INFRASTRUCTURE

The PoE-LED installation involves structured cabling rather than a traditional alternating current (AC) conduit installation. Where traditional AC systems require electrical cables with local power distributed to local drivers within the luminaires, a PoE infrastructure uses structured data cabling that operates on centralized power units and LED drivers connected to the PoE switch.

Single-pair multidrop is defined in IEEE 802.3 as 10Base-T1S. The next step is for the Telecommunications Industry Association (TIA) to develop the specifications of the cabling, potentially enabling PoE technology to greater cost efficiency and as a mainstream solution in the future. See Figure 2.

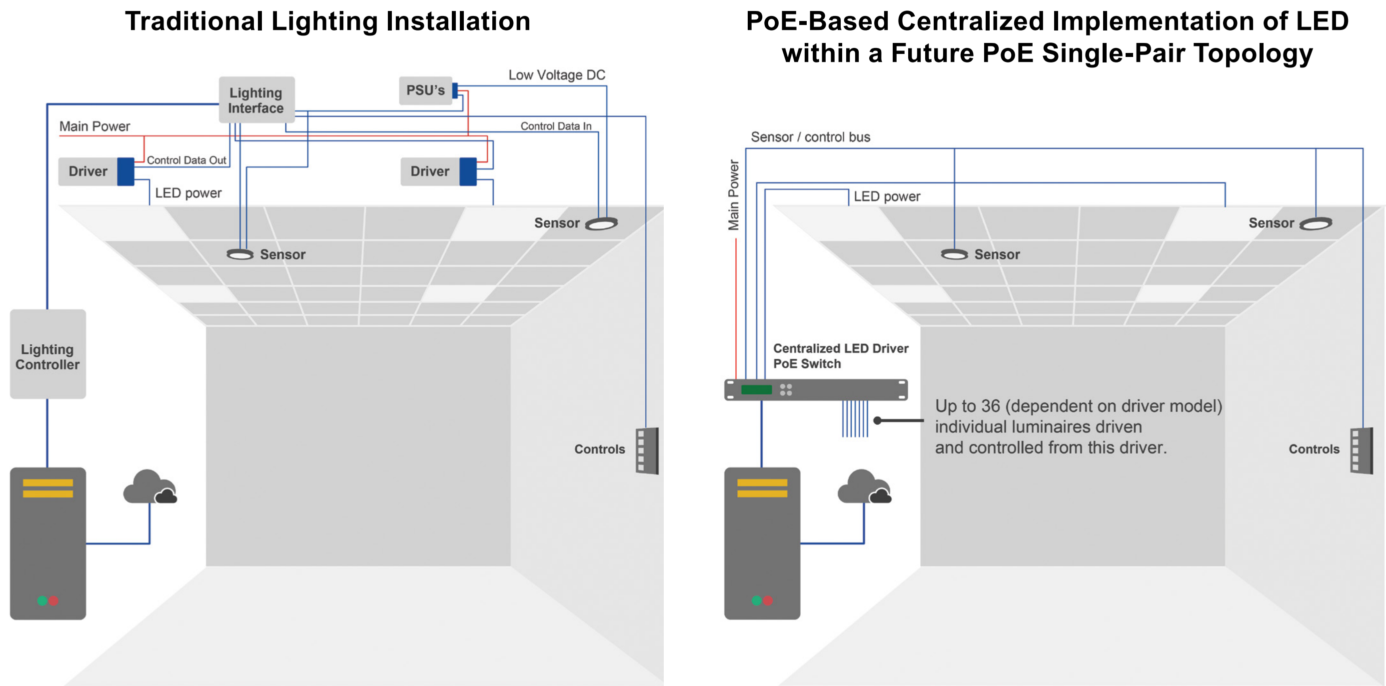

FIGURE 2: Classic LED lighting versus PoE-based lighting within a future PoE single-pair implementation.

A comprehensive category cable infrastructure enables futureproofing of the building by providing a flexible and open integration for new technologies as the needs of the enterprise evolve. The installation of the category cable network is highly standardized and verifiable according to the applicable installation standards. Furthermore, PoE enables the retrofitting of buildings to support integration of technology with physical infrastructure and analytics.

With a PoE topology, users have the choice between mid-span and end-span networks. The dominant end-span architecture uses a network switch that supports PoE. Mid-span, on the other hand, uses an external PoE injector installed between a non-PoE switch and a power distribution (PD) device. Both types of architecture make the transition from the old network environment to a PoE network much easier. For longer lengths, there are PoE extenders available that lessen the need for a traditional local AC line voltage power source by lengthening the distance over which power can be delivered over PoE, and there are ways to daisy chain these extenders to provide power over greater distances.

The latest iteration of the IEEE 802.3bt standard pushes the power level of power sourcing equipment (PSE) to 90 W by utilizing all four pairs of the category cable. Thus, PoE provides compelling benefits over conventional AC power by eliminating the need for electrical wiring and provides ease of installation, increased safety, reduced capital expenditures, and low operating costs.

COMPATIBILITY WITH PoE

Essentially, PoE is brand agnostic and ready for use in all kinds of industries and applications (e.g., commercial, industrial, retail, residential). The PoE infrastructures communicate in a common language. Therefore, different types of systems and devices can be easily connected, configured, and integrated. Open protocols are easier to work with in terms of master system integration and scalability in smart buildings.

The PoE devices should support the open network protocol Message Queuing Telemetry Transport (MQTT) or others including BACnet, AMQP, Dali/KNX, Art-Net, Bluetooth, EnOcean, LoRaWAN, and Thread. Essentially, MQTT is a message protocol for networks with low bandwidth and high latency. Therefore, it is ideally suited for machine-to-machine (M2M) communication. In the IoT, it is used all the way to the connection of cloud environments. The use of IoT makes it easier to share information, control operations, and enhance human interaction.

Protocols are best understood as the languages by which objects communicate with each other. Technically, they enable communication between servers within a network. The early BMS consisted of multiple subsystems that were not interconnected. That is because those systems did not speak the same language. Building operators or managers had to collect and aggregate data from different systems in single or across multiple buildings in order to interpret and analyze the data. Those limitations are now mitigated with the establishment of communication protocols for buildings.

Furthermore, the PoE power supply is a simple plug-and-play setup that can be operated with DC power. Conversion adapters for AC/DC are not required, resulting in reduced energy consumption. The PoE-compatible devices can be connected to the network and are self-configuring. Since only low voltage is used, there is no specific requirement for qualified electrical technicians for both implementation and maintenance. The network can be managed by data cabling installers and IT staff.

> *The PoE is the backbone technology to enable digital building solutions to come to life.*

The PoE standards provide backward compatibility with all previous standards. The installation of the network is highly standardized and verifiable in accordance with applications and installation requirements. Since both power and communication are on one cable, there is less congestion in the installation space because fewer cables are required.

CABLE TECHNOLOGY FOR PoE

From Cat 5e to Cat 8, all category cables support the PoE standards 802.3af, at, and bt but not with the same efficiency or transmission rate capability. The efficiency of PoE is increased by using Cat 6A cable, which supports 10G transmission and also promotes less signal degradation from heat generated during the operation of powered devices. The Cat 6A cables use larger gauge conductors, typically 23 gauge or to a much lesser extent 22 gauge, which is considerably more robust than a standard Cat 6 cable.

The Cat 6A cables provide the ability to push more current without heat loss, driving higher power and wattage capabilities. A shielded Cat 6A cable enhances the cable's transmission properties. It provides the maximum energy output at lower temperatures due to higher heat dissipation (and generation), which allows power to be transmitted over potentially longer distances. Furthermore, Cat 6A supports 10 Gb/s Ethernet for the full distance of 100 m (≈328 ft).

Considering the growth in the number of devices powered by PoE and the number of wireless users, installing category cable with ratings below Cat 6A could place businesses at risk of needing to replace Cat 5e and Cat 6 cabling to support 802.11ax WAPs. Based on the superior performance of Cat 6A to achieve 10G transmission rates and the improved characteristics of heat dissipation, Cat 6A is a reliable choice for future-proofing the digital building infrastructure.

To extend the benefits of an "all-IP" infrastructure in the digital building, a next tech wave is single-pair Ethernet (SPE). Essentially, SPE shall be integrated with existing 4-pair (4P) PoE cabling to bring Ethernet packages beyond 100 m (≈328 ft) and/or to replace old legacy buses in auxiliary systems by an IP connection—like HVAC systems, lighting, or smart sensors' access points (e.g., Piconet, EnOcean, Zigbee). The technology of SPE is a notable add-on to a digital building infrastructure, allowing Ethernet to reach 250, 400, or even 1000 m (≈3281 ft) links with 10 Mb/s, including power over dataline (PoDL), which is the single-pair version of PoE.

CONVERGENCE IN DIGITAL BUILDINGS

There is a convergence of information technology (IT) with operational technology (OT). This convergence of IT and OT brings the data from the physical equipment and devices into the digital realm to enable smart building applications. The digital information collected by the physical devices is used to monitor, analyze, and influence the physical operational environment. When successfully implemented, IT and OT convergence can merge business processes, insights, and controls into a single uniform environment.

The purpose of IoT devices is to obtain data, such as temperature, motion, humidity, and light. The data is useful within its dedicated solution, but it can only be used in full when systems are converged. The data from the sensors, for example, are useful for many building services, such as access control, fire detection, intruder alarms, surveillance, and lifts/elevators to increase energy efficiency, occupancy, security, safety, and comfort.

Connected buildings have one or several IP-based building network infrastructures that support multiple coexisting applications and services. There is a trend towards several networks linked via virtual LAN (VLANs) or a backbone to enable transfer and sharing of data with centralized monitoring and management. When data is centrally recorded, analyzed, compressed, and made available system-wide, remarkable optimizations can be achieved. Operating processes can be continuously optimized using building information modeling (BIM).

THE PoE LIGHTING AND PoE EMERGENCY LIGHTING

The progressive development of PoE technology enables the power supply of a growing number of applications and services in buildings via data cables. Intelligent solutions based on PoE technology are becoming increasingly widespread. The most relevant applications in the context of "smart buildings" are PoE lighting and PoE emergency lighting.

The PoE Lighting

For buildings of all sizes, PoE lighting is used as a flexible and at the same time sustainable lighting solution. Compared to conventional lighting systems, the smart concept scores highly with lower effort for installation, maintenance, and operation, as well as reduced energy consumption and CO2 emissions. The integration of sensors, LED luminaires, and intelligent controls offer attractive options for optimized operation.

Because PoE lighting is IP-based, the lighting becomes intelligent. The lighting is easily automated by connecting the control to the data network. Various personalized lighting scenarios can be created, in addition to the more common functionality that the light comes on automatically when it is needed and goes off again when there is no one in the room. This function ensures that lights are not left on overnight. Control via the data network further enables daylight harvesting, in which LED lighting supplements the daylight in the room to the desired illuminance at any time. The setpoint can be specified individually for each area and for each workstation.

Furthermore, LEDs require significantly less power than conventional luminaires. However, LED luminaires show their full potential, in combination with appropriate sensors and an intelligent control system, that quickly and automatically adjust the illuminance to the respective requirements. In this way, a reduction in power consumption is possible compared to conventional lighting. Conventional lighting control systems are commonly more complex, can be limited in interface options, and are typically associated with significantly higher costs for initial installation, operation, and maintenance. In addition, licensed electricians are required for installation.

Emergency Lighting with PoE

Emergency lighting plays a very important role in building safety. Many installers encounter mains-independent emergency lighting every day in ceilings, on walls, or above doors in various public buildings, factories, campuses, or company offices. In emergency situations, when the power fails, emergency lighting provides sufficient orientation for building evacuation. Escape routes are reliably marked. If the regular mains-dependent lighting switches off, it can otherwise get dark very quickly with obvious detrimental consequences.

To be independent of the mains in an emergency situation, emergency lighting is provided by rechargeable batteries or a power generator. From the time of the power failure, it must be possible to supply the emergency lighting independently of the mains for at least three hours according to British Standard (BS) 5266 or 90 minutes according to Underwriters' Laboratories (UL) 924.

It is also important that the lighting is switched on immediately at an average level of 1.0 foot-candle (fc) and minimum level of 0.1 fc. The maximum to minimum illumination level ratio must be 40:1 or less according to the National Fire Protection Association (NFPA) 101 standard. Emergency lighting components, such as signs with illuminated pedestrians or spotlights for corridors and open spaces, are easy to implement via plug-and-play data cable networks.

Emergency lighting today mostly works with LED and rechargeable batteries. With LED emergency lighting, energy efficiency is a major advantage; the luminaire is activated for longer due to a more efficient use of the battery.

> *Because PoE lighting is IP-based, the lighting becomes intelligent.*

BUILDING OPERATIONS AND FUNCTIONALITY

Traditional building systems are structured for reactive decision-making. The Building Internet of Things (BIoT) connected buildings rely on big data technology to enhance the capacity for proactive and rather prescriptive decision-making. For example, an IoT connected HVAC system via a sensor will not only trigger maintenance alerts when components are approaching end-of-life, but it will also order replacement parts online and book an engineer to perform maintenance. Centralized management and control of building applications allow for functional durability. Through preventive maintenance and early fault detection, the lowest possible downtimes are achieved.

SUSTAINABILITY

Buildings typically consume vast amounts of energy to operate. They are responsible for 30 to 40 percent of a city's total emissions. Smart buildings offer a viable solution to increased energy demands where emissions can be reduced through optimization of energy consumption with the possibility of reducing carbon footprint, fostering sustainability, and endorsing eco-friendly alternatives.

Organizations can use tools that identify efficiencies along with providing insights allowing smart building decisions to be made to save energy consumption and operational costs. Sensors can be added to various appliances to gather information, ranging from heating systems to ventilation equipment.

If a certain component is either overworked or underused, operations can be adjusted accordingly. For example, an occupancy sensor can be added to reduce an environment's carbon dioxide levels. When this sensor identifies less movement, it sends a signal to the building management system to turn off heating, ventilation, and lighting. When people return, these systems revert to their regular mode.

HUMAN-FOCUSED BUILDINGS

Indoor environment quality (IEQ) influences the health and well-being of occupants in living and working spaces. The IEQ includes indoor air quality (IAQ), acoustic conditions, and occupant control over lighting and thermal comfort. To achieve high IEQ standards, it is more cost convenient to include these factors in the design phase of a building and not as an add-on after occupancy. In general, environmental conditions, such as temperature, lighting conditions, flicker, and air quality influence the performance, quality of work, and overall health of the occupants.

Digital buildings balance efficiency and occupant experience. They play an important role in the feel-good factor since they can provide optimal control of various aspects that contribute toward employee satisfaction and productivity improvements.

Further factors to consider are post-Covid and the need to bring people back into the workplace. The workplace market is moving to an even more human-centric direction. There has been a certain shift in mentality toward better working environments post-Covid.
It is ideal to design the workplace around people instead of designing the people around the workplace. Ultimately, it is about achieving design goals through a human-centered experience of physical and psychological comfort (e.g., lighting, air distribution, and occupants' spatial needs). See Figure 3.

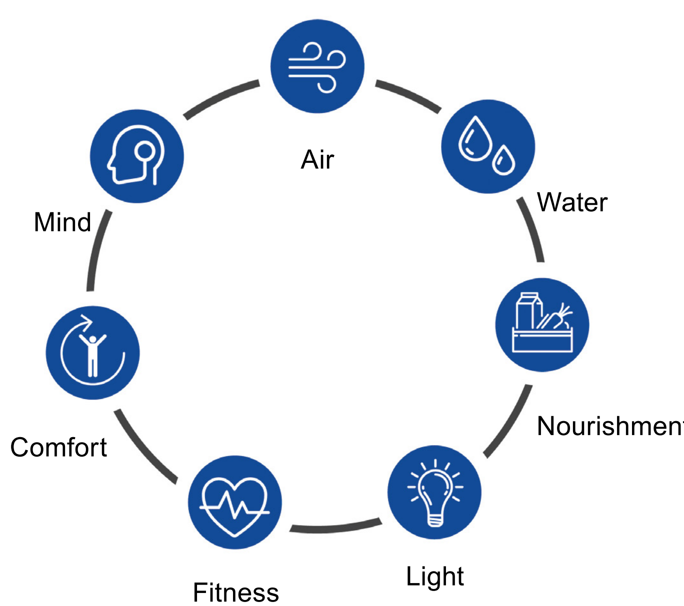

FIGURE 3: The seven concepts of the WELL building standard.

SECURITY

As smart building technologies evolve, there is a concern about cybersecurity. This requires having only the data points needed to achieve the desired outcome being exchanged between systems. Using methods, such as segmentation, least privilege, firewalls, demilitarized zones (DMZs), and authorization are followed to maintain network security. As for any security posture, strong authentication and access control should be the first step for protection. Security is not just an add-on, but rather it is an immune system for an organization.

An occupancy sensor can be added to reduce an environment's carbon dioxide levels.

VERTICAL APPROACH OF DIGITAL BUILDING SOLUTIONS

Vertical integration is an essential part of an effective digitalization strategy. Increasing the number of data points within an IoT-enabled building enhances the variety and volume of information that can be collected and communicated by leveraging the number of sensors and components. Over time, total cost of ownership (TCO) and ease of implementation have been growth drivers. A vertical approach permits end-to-end solutions toward specific problems present in buildings, such as cost optimizations and energy savings.

A data fabric is generated everywhere in the environment where an ecosystem of sensory components in the building becomes part of the base infrastructure. No matter how unified the whole may appear, the parts each component plays are discrete and necessary. Considering the flexibility of a digital building with a PoE infrastructure, the more connected a building's system becomes with greater variety, volume, and velocity of data generation, the higher the potential for intelligent decision-making. See Figure 4.

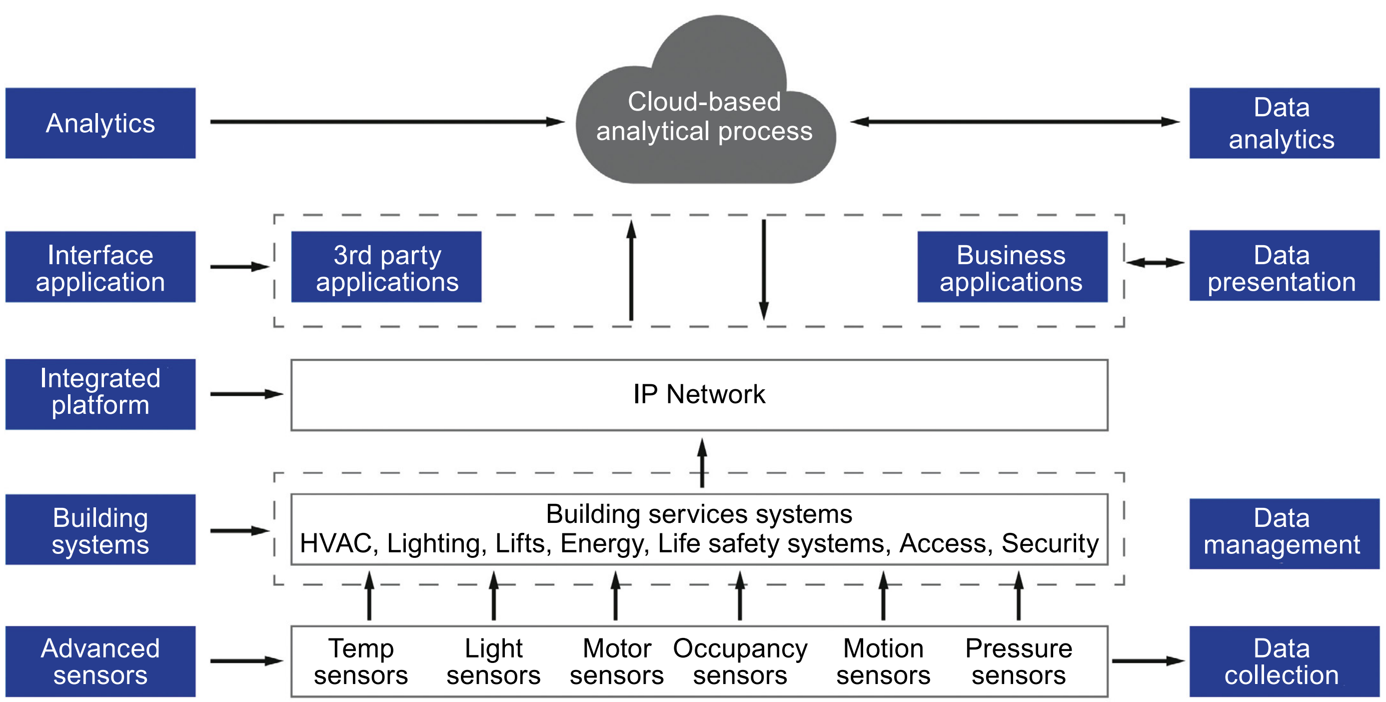

FIGURE 4: IoT intelligent connected building.

RETROFITTING OLDER BUILDINGS WITH SMART TECHNOLOGY

Existing buildings comprise the largest segment of the built environment. It is important to initiate energy conservation retrofits to reduce energy consumption and the cost of heating, cooling, and lighting. Conserving energy is not the only reason for retrofitting existing buildings; retrofitting can often be more cost-effective than building a new facility.

Retrofits are an option in all types of buildings, including commercial, hotels, and data centers. They can be designed around sustainability initiatives to reduce operation costs and environmental impacts. They can also increase the buildings' adaptability, durability, and resilience.

There is the opportunity to work with the existing framework of buildings. When deciding on a retrofit, it is important to consider upgrading for accessibility, safety, and security simultaneously. The advent of IoT has simplified the introduction of smart technology. Sensors and the equipment that sends the data to the cloud are designed to be low-energy and low-maintenance. Data can also be transmitted directly under one cloud platform where the information can be displayed and analyzed.

CONCLUSION

The application areas presented in this article offer users practical optimization approaches with short amortization cycles. Owners and investors can adapt goals and plans for the long-term management of the space. Data visualization in digital buildings provides information from the assets in real time. The building itself becomes a platform for a host of different digital systems, services, and functions which can change to match the strategy. It makes it relatively easy to switch building functions over time and potentially eliminate obsolescence.

A digital building solution using PoE technology will ensure a long-term, cost-effective, and positive future for property owners who enable the sustainability of the building and the health and well-being of the building's occupants. Building owners and investors will be able to adapt goals and plan for long-term management of properties, as the visibility of data in digital buildings will provide information from all assets in real time. While the building itself becomes a high value asset, it could attract premium tenants who are willing to pay high rental fees.

Furthermore, PoE technology is the perfect platform to host and power many different solutions, such as lighting, HVAC, and security, as well as IoT devices, such as sensors, gateways, and automated window controls. As a plug-and-play data network, it is simple to install, flexible, and safe, offering quick returns on investment through reduction of energy costs, automation of manual tasks, and an improved experience for occupants today and into the future.

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