



智能大厦科技

Smart Lighting Solutions



Ir Dr. Sam C. M. Hui

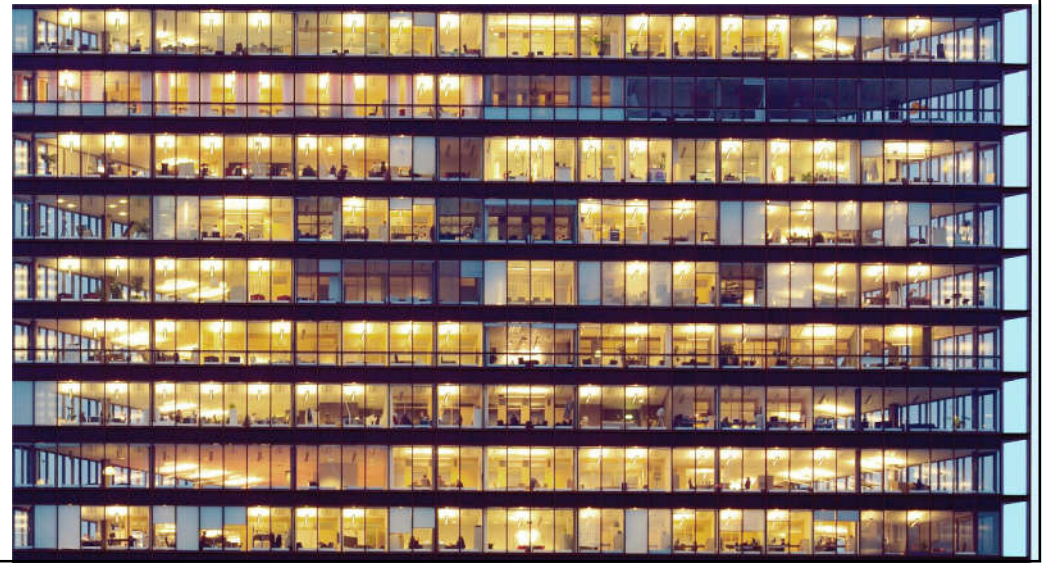
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Contents



- Basic principles
- Lighting control techniques
- Wired & wireless systems
- Smart lighting systems
- Lighting intelligence





Basic principles

- A good lighting system design includes a good lighting controls design to enable users manually or automatically to:
 - Turn the lights ON & OFF using a switch; and/or
 - Adjust light output up & down using a dimmer
- Benefits for the owner:
 - Flexibility to satisfy user visual needs
 - Automation to reduce energy costs (on electricity use & demand) & improve sustainability



Benefits of good lighting controls

Visual Needs	Energy Management & Sustainability
<ul style="list-style-type: none">• Change space appearance• Facilitate different functions of the space• Alter atmosphere & mood• Reduce glare & visual discomfort conditions• Increase user satisfaction by providing users the ability to control their lighting	<ul style="list-style-type: none">• Reduce both energy demand & energy consumption• Reduces building operating costs• Comply with building energy codes• Facilitate more efficient building operation & maintenance• Provide data & information for building optimization





Basic principles

- The aim of lighting controls is to encourage the maximum use of daylight & to avoid the unnecessary use of lighting when spaces are unoccupied
- Benefit of a good lighting control system:
 - Occupant satisfaction & productivity
 - Planning flexibility (suit work layouts & patterns)
 - Better facility management information (e.g. for security & maintenance)



Basic principles

- Five basic methods of lighting control:
 - 1. Localised manual controls
 - Using local switches & dimmers, remote control
 - 2. Time switches
 - For buildings with fixed occupancy times
 - 3. Occupancy detection
 - Using occupancy or presence sensors
 - 4. Lighting level (e.g. to integrate daylight)
 - 5. Scene set control (different lighting schemes)

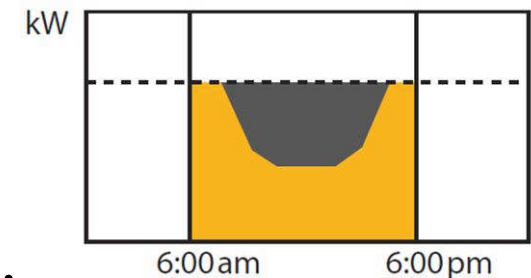
Lighting control panel of a lecture theatre





Basic principles

- Integrate lighting controls with BAS
 - Lighting can be turned on, off, or dimmed with a building automation or lighting control system based on time of day, or on occupancy sensor, photo sensors & timers
- Common lighting control functions:
 - 1. Occupancy control, 2. Time scheduling
 - 3. Daylight control, 4. Task control
 - 5. Personal control, 6. Variable power shedding



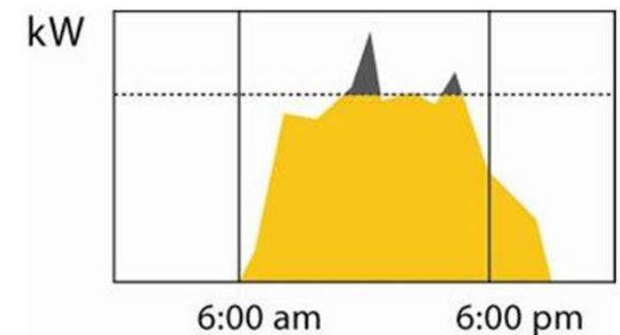
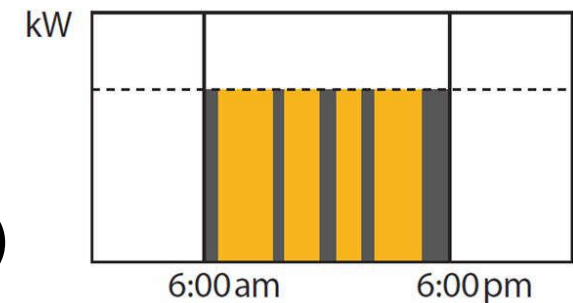


Basic principles

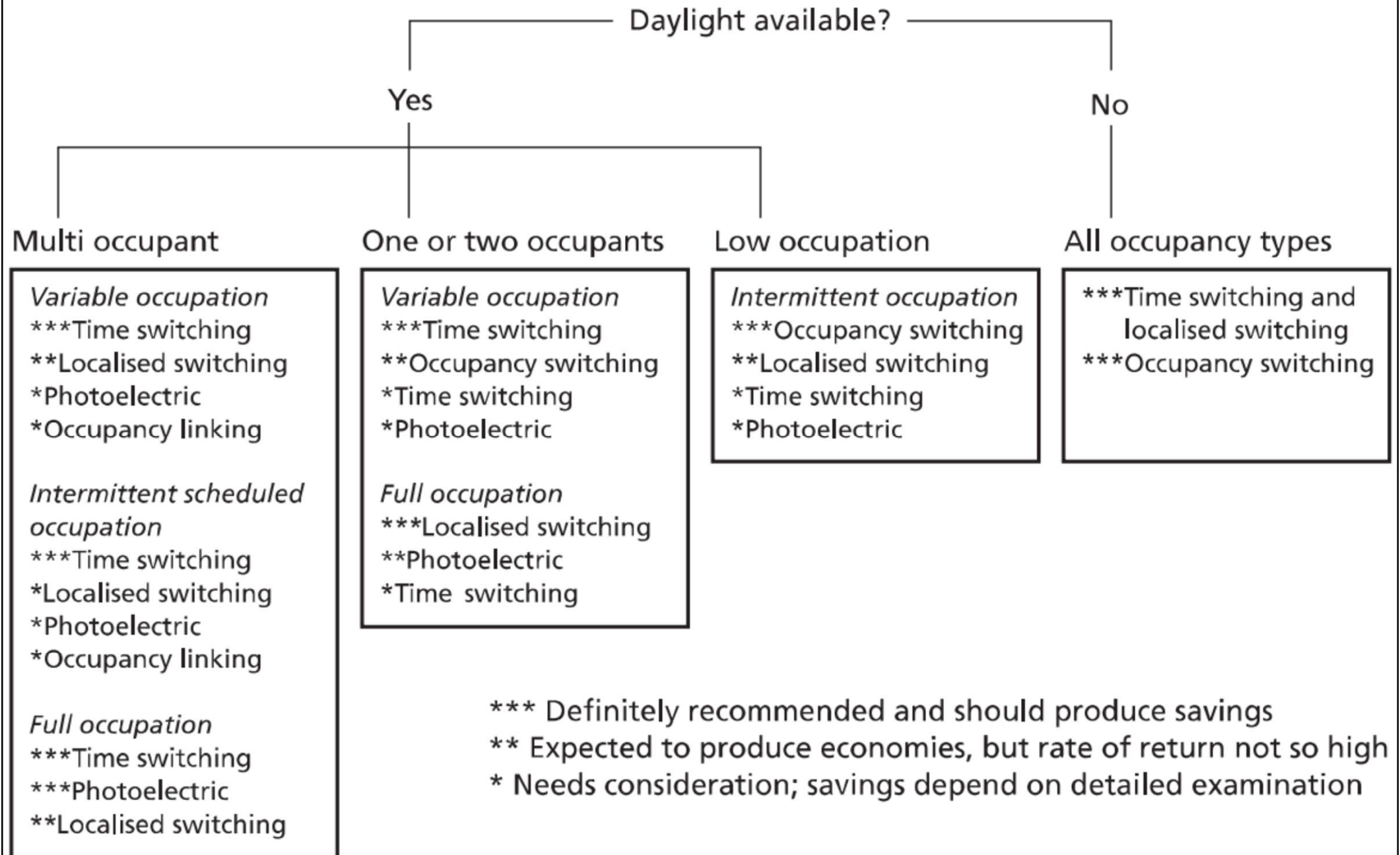
- Typical control strategies:



- Manual control (local/group)
- Time scheduling (time-based control)
- Occupancy sensing (vacancy sensing)
- Daylight response (to reduce electric lights)
- Institutional task tuning (user preference, scene)
- Colour tuning (various effects)
- Data generation (intelligence)
- Demand response (↓demand costs)



Selection of lighting control strategy





Basic principles

- In recent years, lighting controls have evolved two additional capabilities:
 - Adjust light source colour, including shade of white light (using LED light source)
 - Generate data via measuring and/or monitoring
- Basic functions of lighting controls
 - Switching (ON/OFF)
 - Dimming & adjusting light intensity
 - Colour & correlated colour temperature (CCT)



Basic & advanced functions of lighting controls

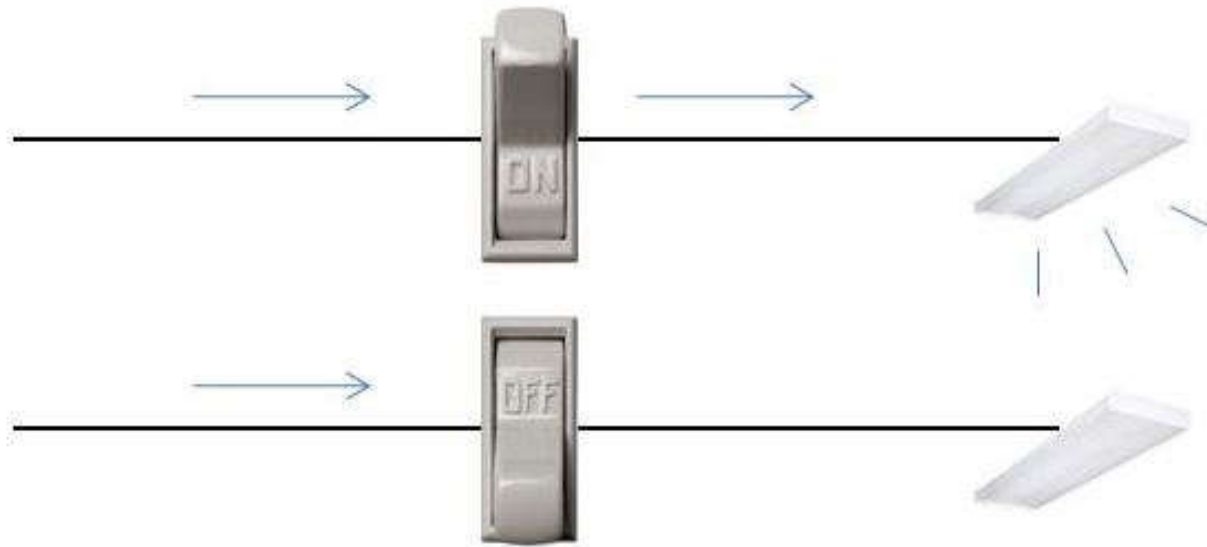
(a) Basic functions:

WHAT	HOW
Produce the right amount of light...	Light output (intensity) dimming
...where the light is needed...	Zoning of luminaires to controllers
...and when the light is needed...	Automatically reduce lighting when the space is unoccupied

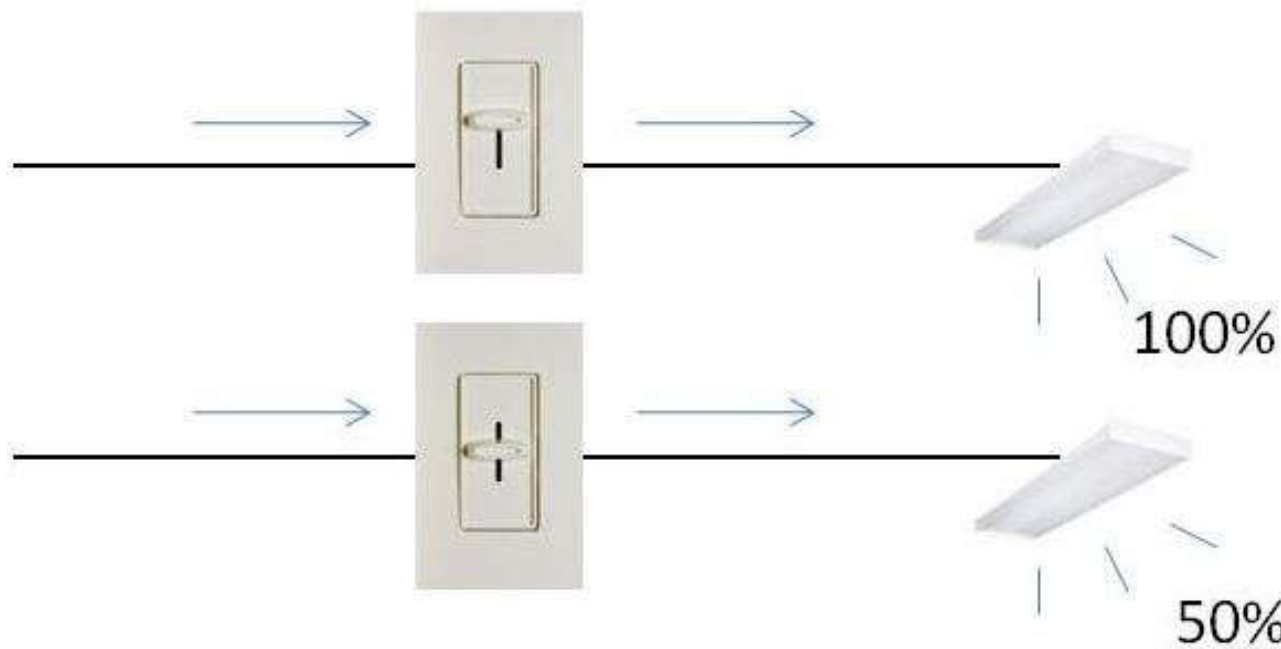
(a) Advanced functions:

WHAT	HOW
Produce light at the right colour or shade of white light...	Separately dimming arrays of LEDs with different colours or white-light correlated colour temperatures (CCTs)
...allow remote programming and control...	Control systems with programming and lighting management capability
...and tell you how your lights are performing...	Centralized intelligent control systems with measuring and/or monitoring/alarm capability

Switching & dimming lighting controls



(a) Switching (ON/OFF)



(b) Dimming

Lighting control of correlated colour temperature (CCT)



5500K, Full on 100%



3800K, Dimmed to 75%



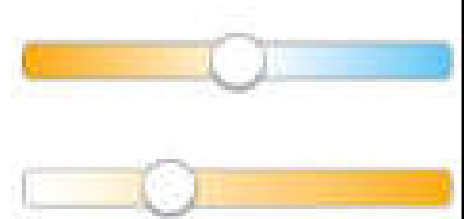
2400K, Dimmed to 50%

(Source: <https://lightingcontrolsassociation.org/2017/07/21/introduction-to-lighting-controls/>)

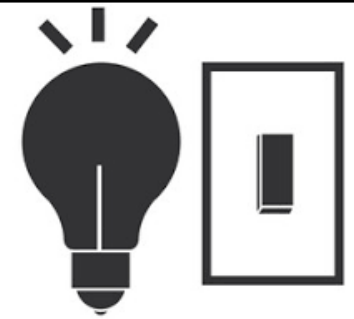


Basic principles

- By adjusting the intensity of one or more layers of lighting, lighting controls can:
 - Change space appearance
 - Facilitate different functions of the space
 - Alter atmosphere & mood
 - Increase user satisfaction by providing users the ability to control their lighting
 - Reduce glare

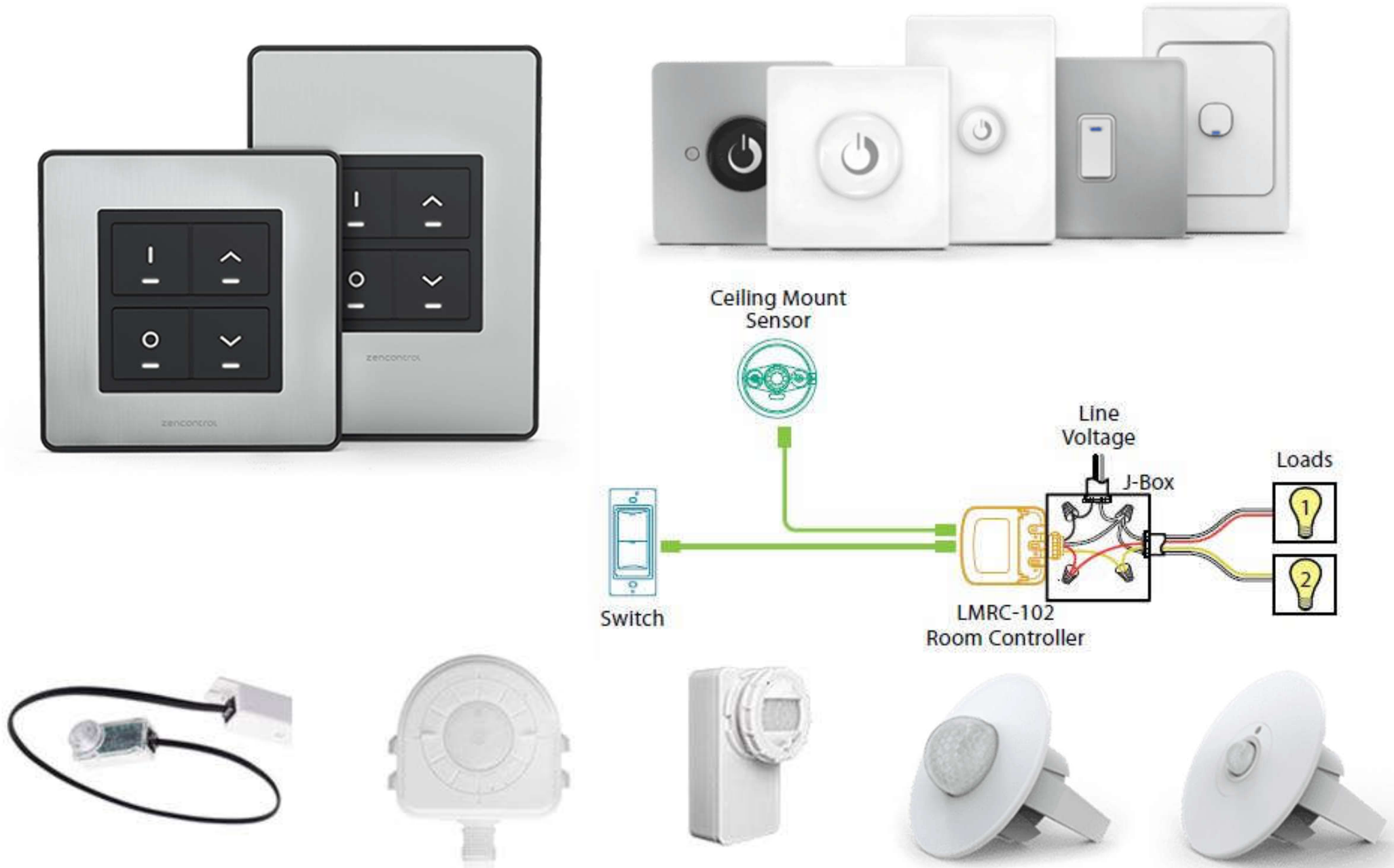


Lighting control techniques



- General types of lighting controls
 - 1. Standalone devices (luminaire-based)
 - Autonomous operation of a lighting load, which may be a luminaire or luminaires installed on a switch leg
 - Standalone embedded sensors
 - 2. Room-based control systems
 - A package of lighting controllers & input devices designed for autonomous room-based operation
 - 3. Centralized building control systems
 - Programmable lighting control for entire floors, buildings or campuses

Standalone lighting control panels & embedded occupancy/light sensors

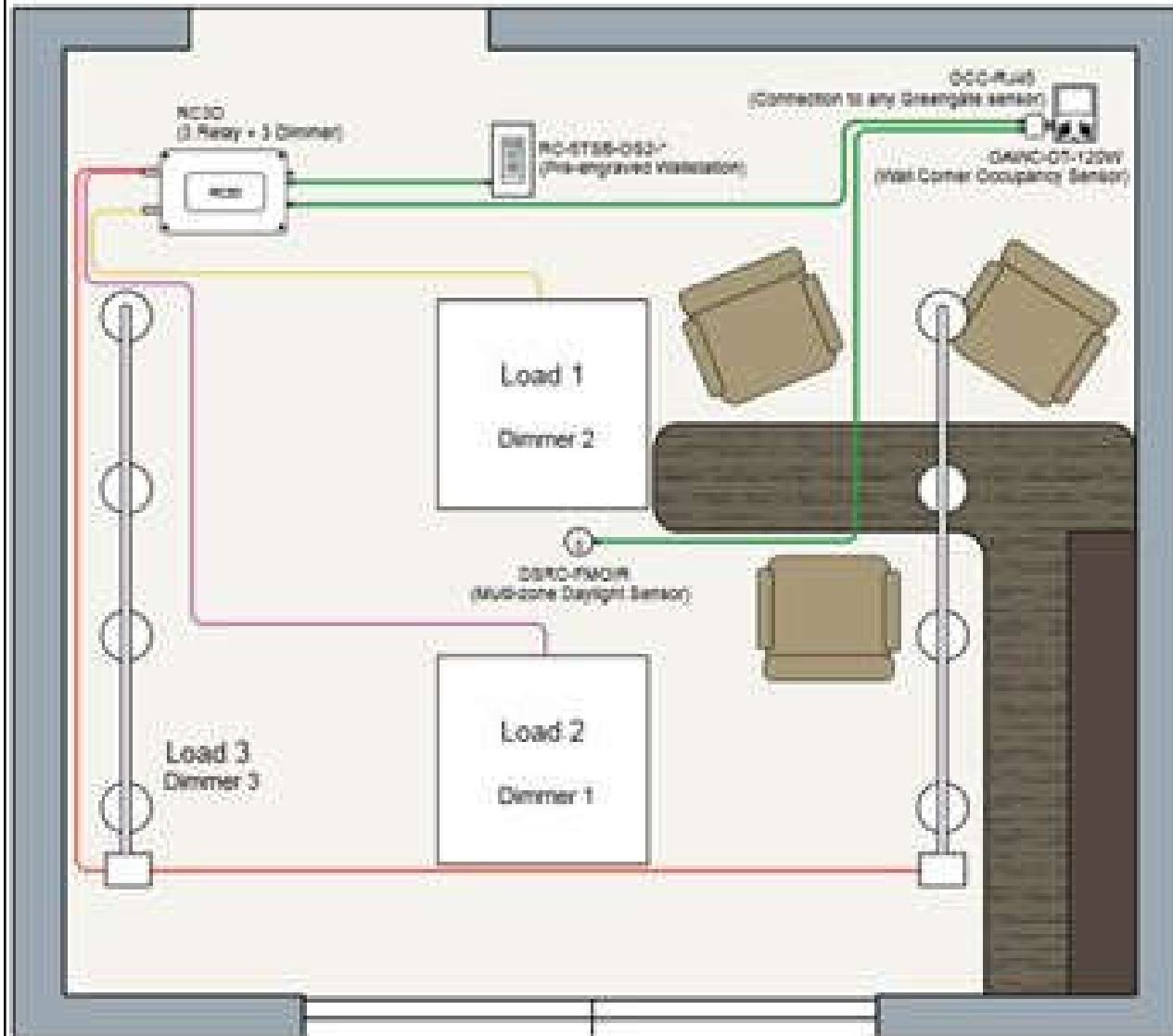


(Source: <https://lightingcontrolsassociation.org/2017/07/21/introduction-to-lighting-controls/> & <https://www.intelligentenvironments.co.nz/all-latest-trends/standalone-lighting-control/>)

A room-based luminaire lighting control in a small office

Room Controller QuickKit

ROCK-OS3-OS2-W1-D1-W



Product Legend



QTY1: RC3D
3 RELAY + 3 DIMMER



QTY1: RC-ETSB-OS2-W
(HALF LIGHTS, FULL LIGHTS, RAISE, LOWER, ALL OFF)



QTY1: DSRC-FMOIR
DAYLIGHT SENSOR



QTY1: OCC-DT-120W
WALL CORNER VACANCY SENSOR



QTY1: OCC-FUH5
OCCUPANCY SENSOR FUH5 CONNECTOR



QTY1: GGRJ45-10-G
QUICKCONNECT CABLE 10'



QTY2: GGRJ45-25-G
QUICKCONNECT CABLE 25'

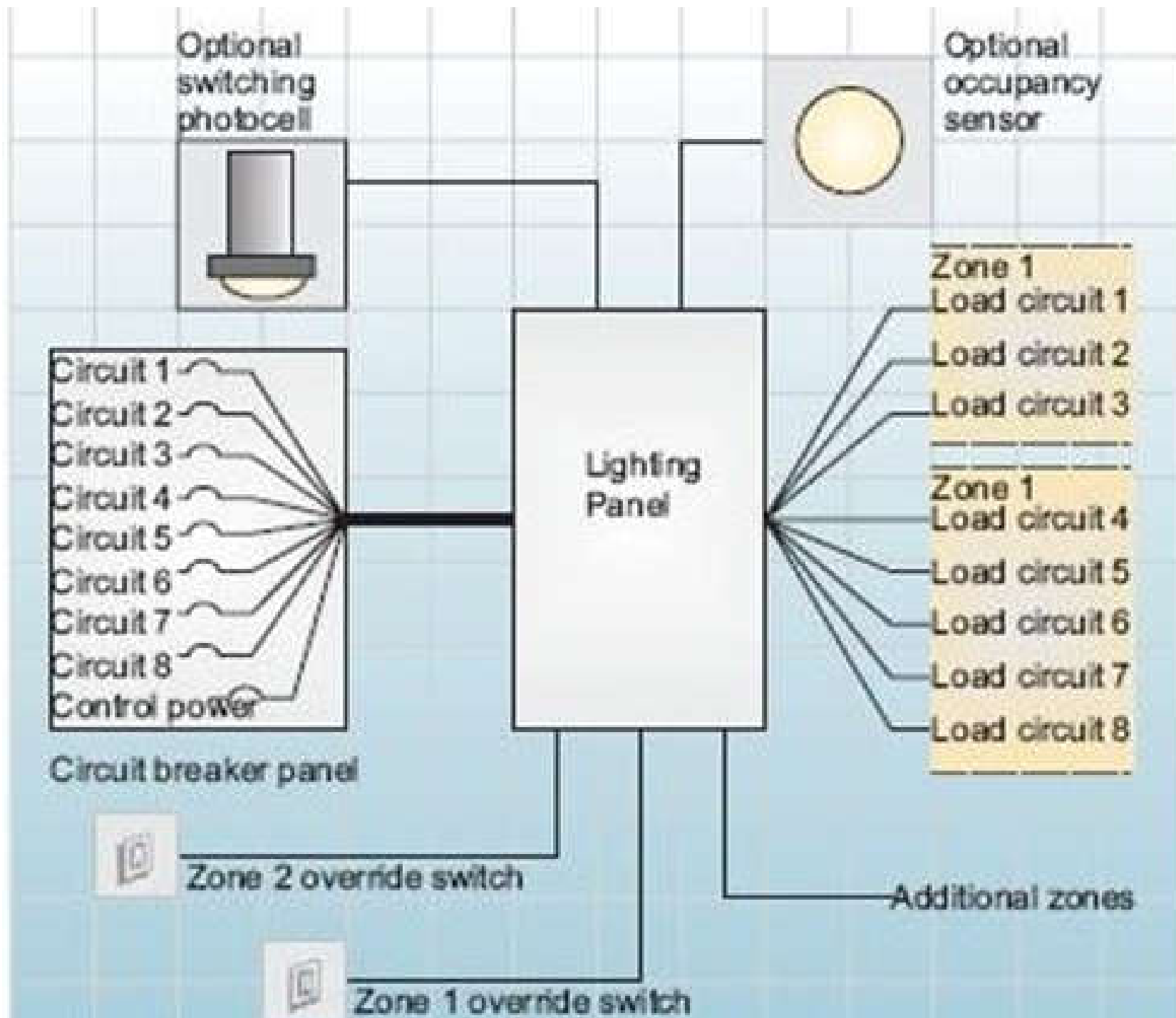


RECESSED FIXTURE

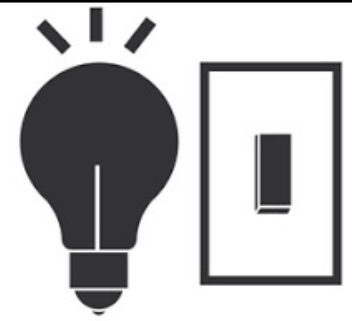
SINGLE BOX PACKAGING WITH WIRING DETAIL
AND INSTALLATION

FOR GUARANTEED COMPATIBILITY REFER
TO PREFERRED COOPER LIGHTING FIXTURE
INFORMATION BELOW

Centralized intelligent networked lighting control systems



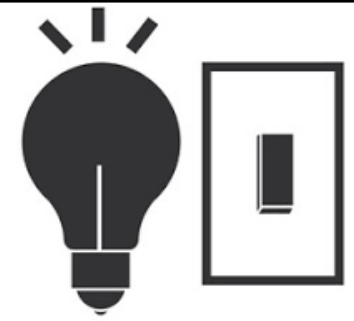
Lighting control techniques



- Typical lighting control techniques & tools
 - Manual control (switches)
 - Timed control (timeclocks)
 - Presence detection
 - Absence detection
 - Photocells
 - Daylight linking
 - Constant illuminance adjustment
 - Dimming & regulation



Lighting control techniques



- Occupancy sensing detection
 - Passive infrared detectors
 - Microwave detectors
 - Ultrasonic detectors
- Photocells & daylight linking
 - Measure available light at a specific location
 - Switch off or dim/regulate the electric lighting
 - Can adjust for constant illuminance at working plane
- Dimming: by supply voltage or electronic



Daylight linking of luminaires from left to right

Windows
(w/ daylight)

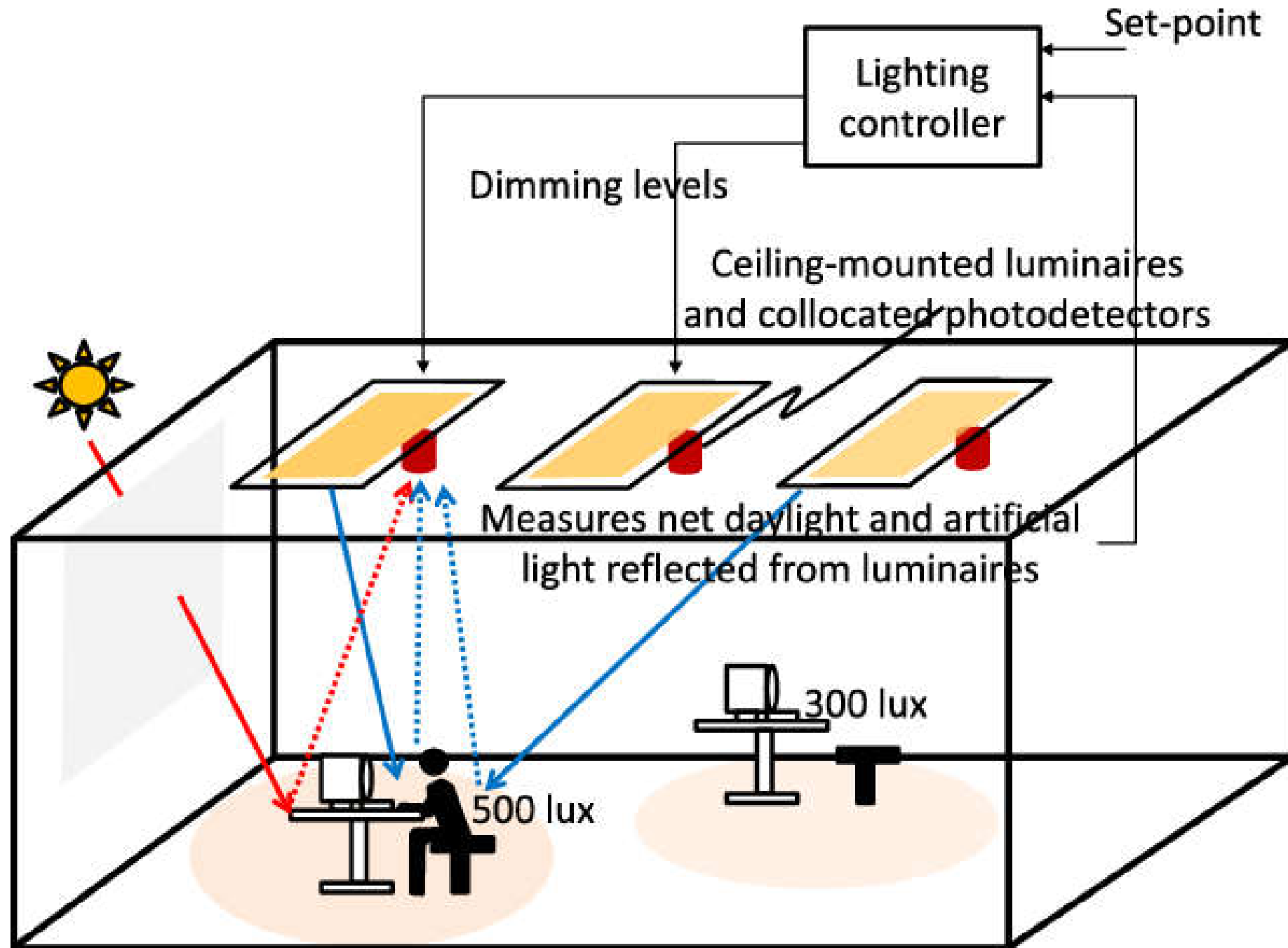
Electric light dimmed
(near windows)

Electric light on fully
(away from windows)

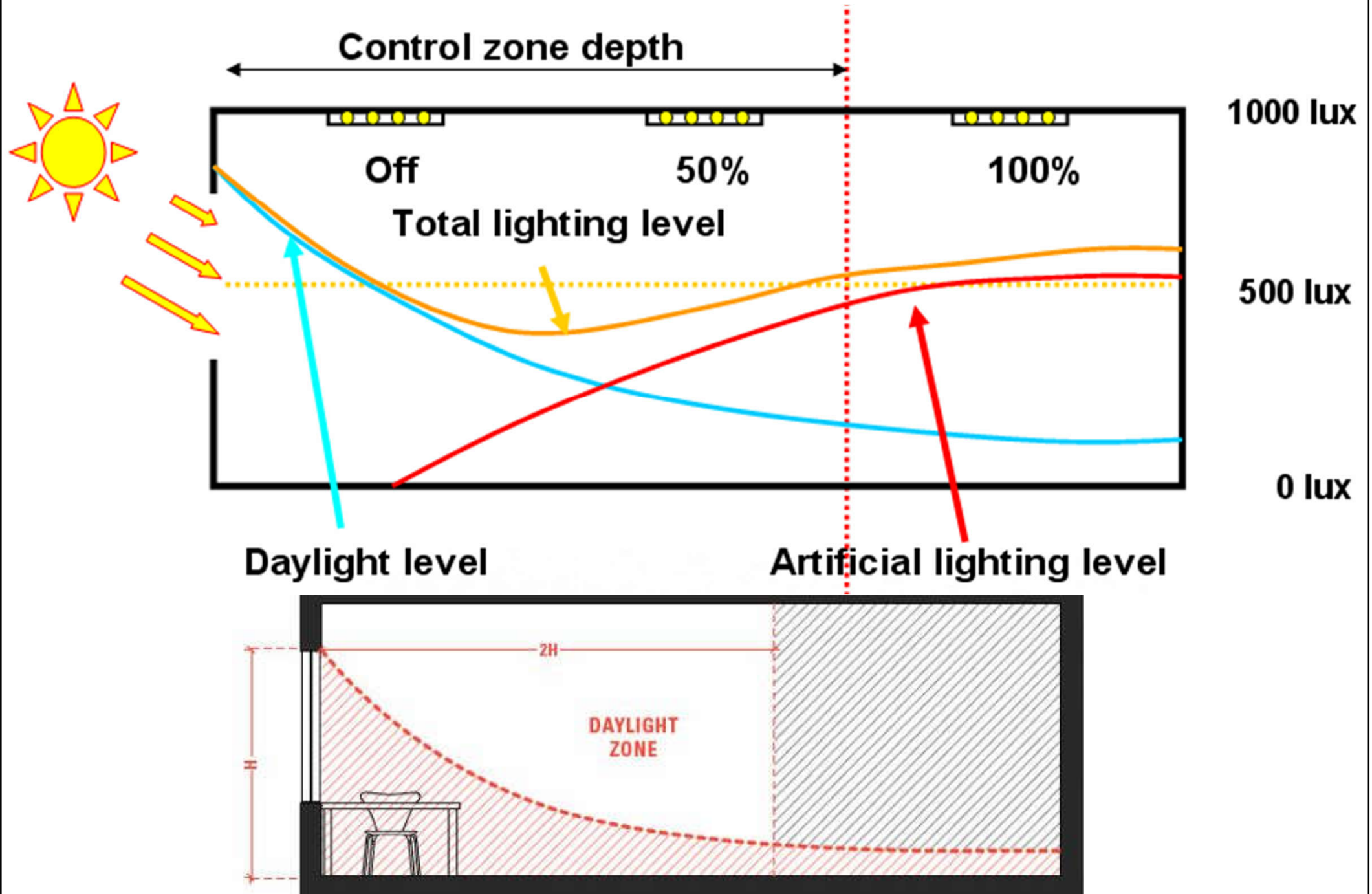


(Source: SLL, 2016. *Control of Electric Lighting*, Lighting Guide 14, Society of Light and Lighting (SLL), London.)

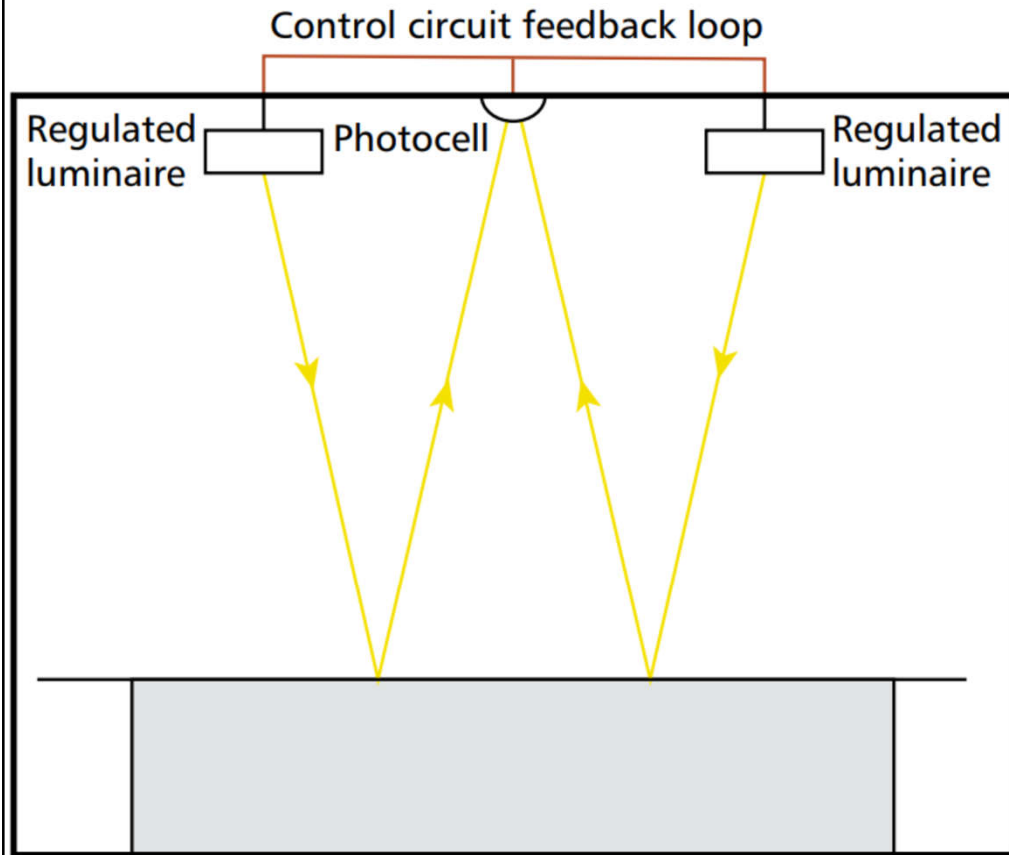
Photodetector based lighting control system



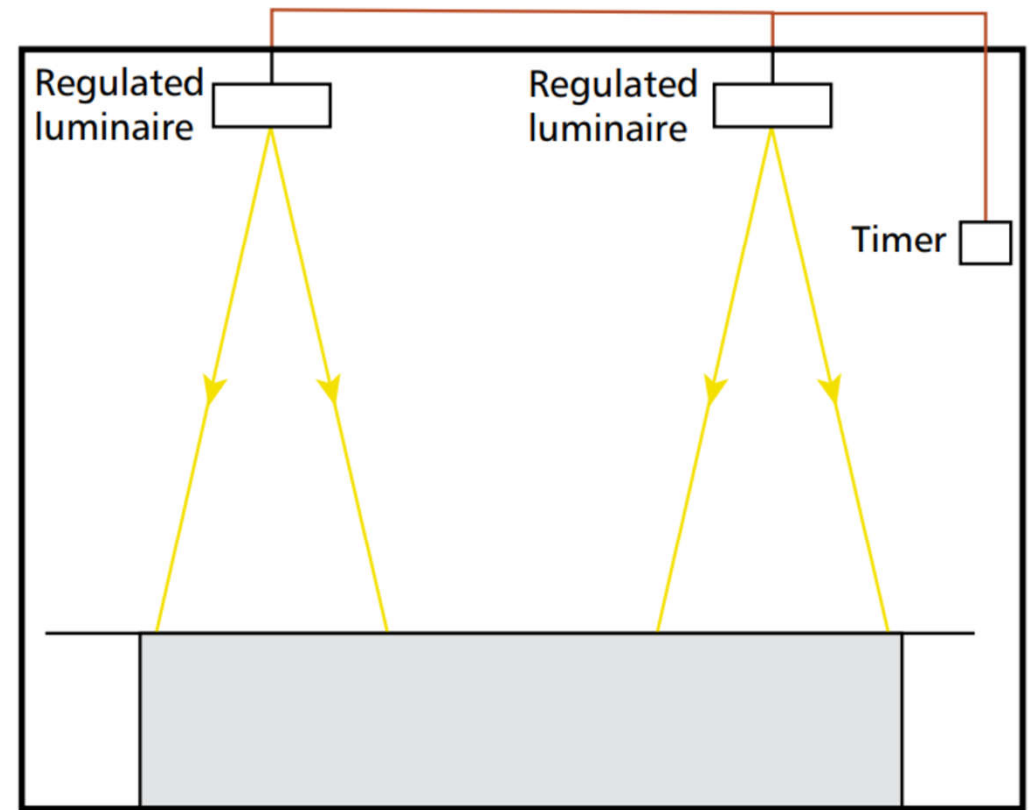
A room with the profiles of daylight, artificial and total lighting



Lighting control for constant illuminance adjustment



(a) A photocell is used to measure the reflected light from the working plane to adjust the light output to the required output



(b) a timer/data connection is used to regulate the luminaire output at a pre-set level based on 'hours run/maintenance offsets' feedback from the luminaires and manufacturer's data on lamp degradation

Wired & wireless systems

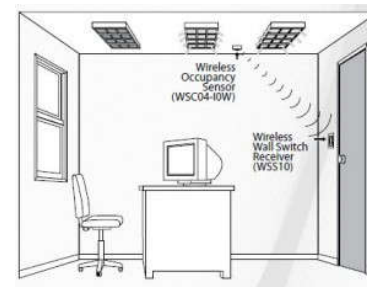


- **Wired systems**

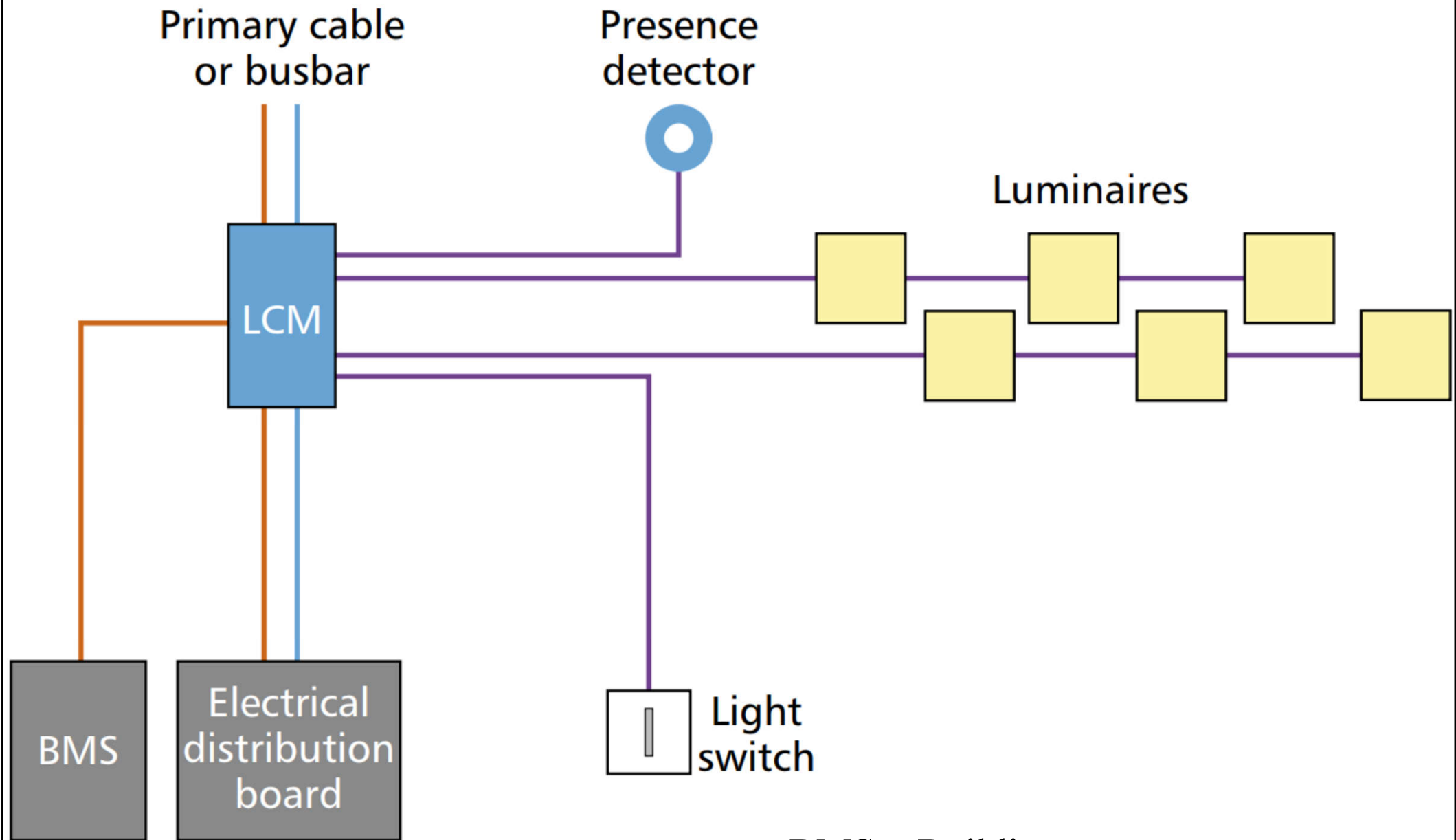
- Line-voltage wiring (powerline communication)
- Low-voltage wiring (dedicated pathway for control signals, analogue)
- Digital low-voltage wiring (digital binary signals)

- **Wireless systems**

- Eliminate control wiring
- Control signals from a wireless transmitter to a wireless receiver in a lighting controller

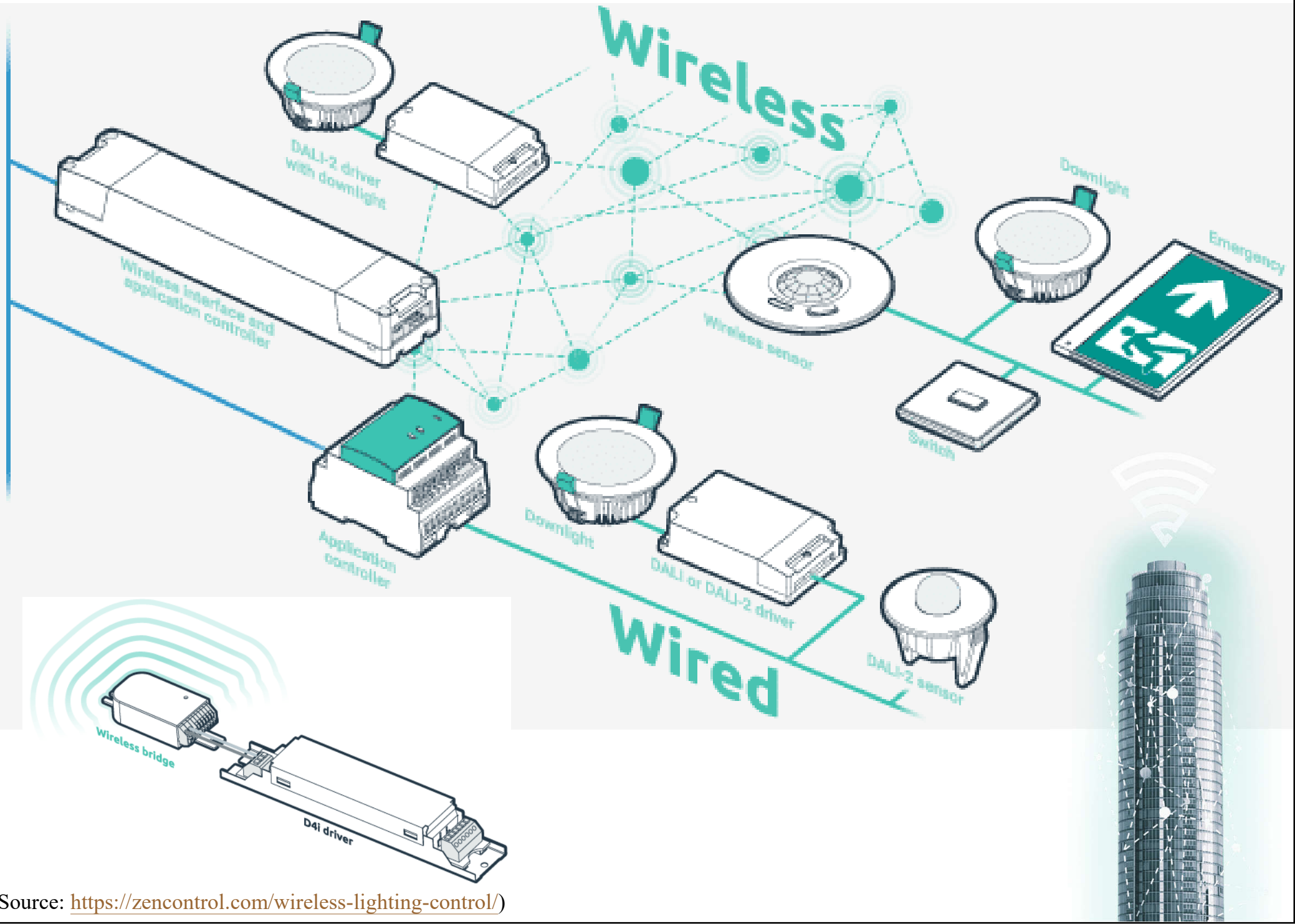


Luminaires connected to a lighting control module (LCM)

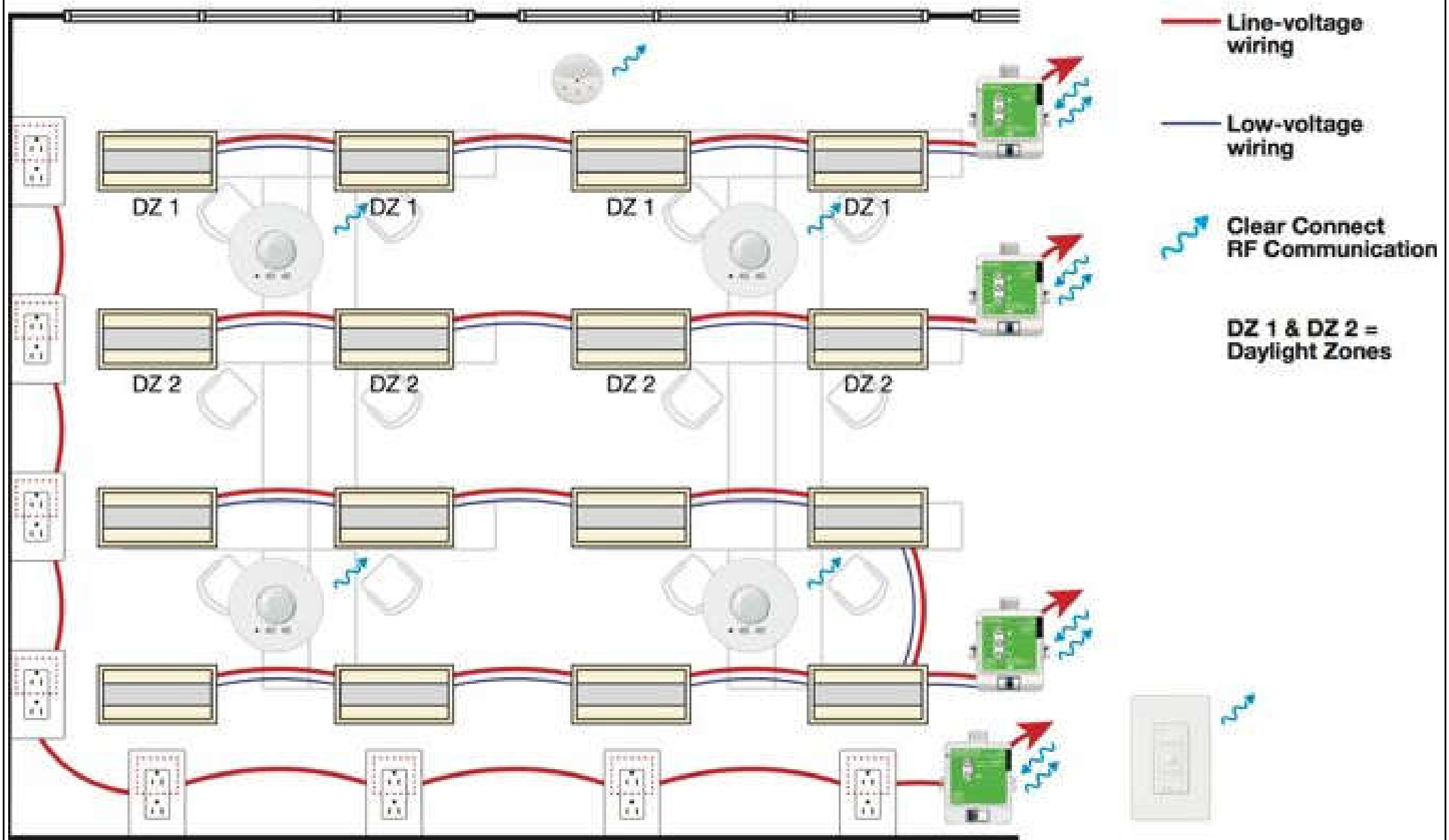


BMS = Building management system
LCM = Lighting control module

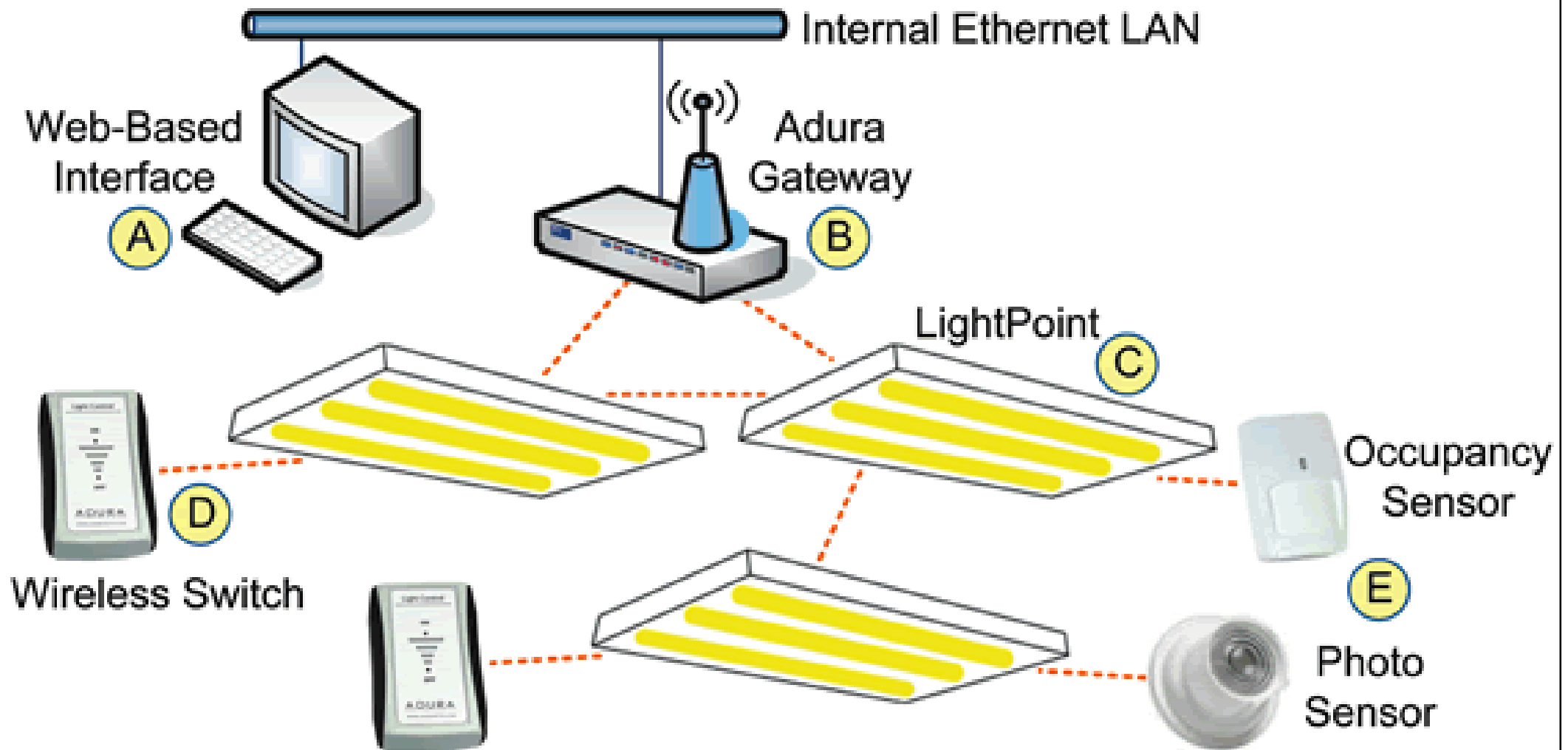
Wired & wireless lighting control



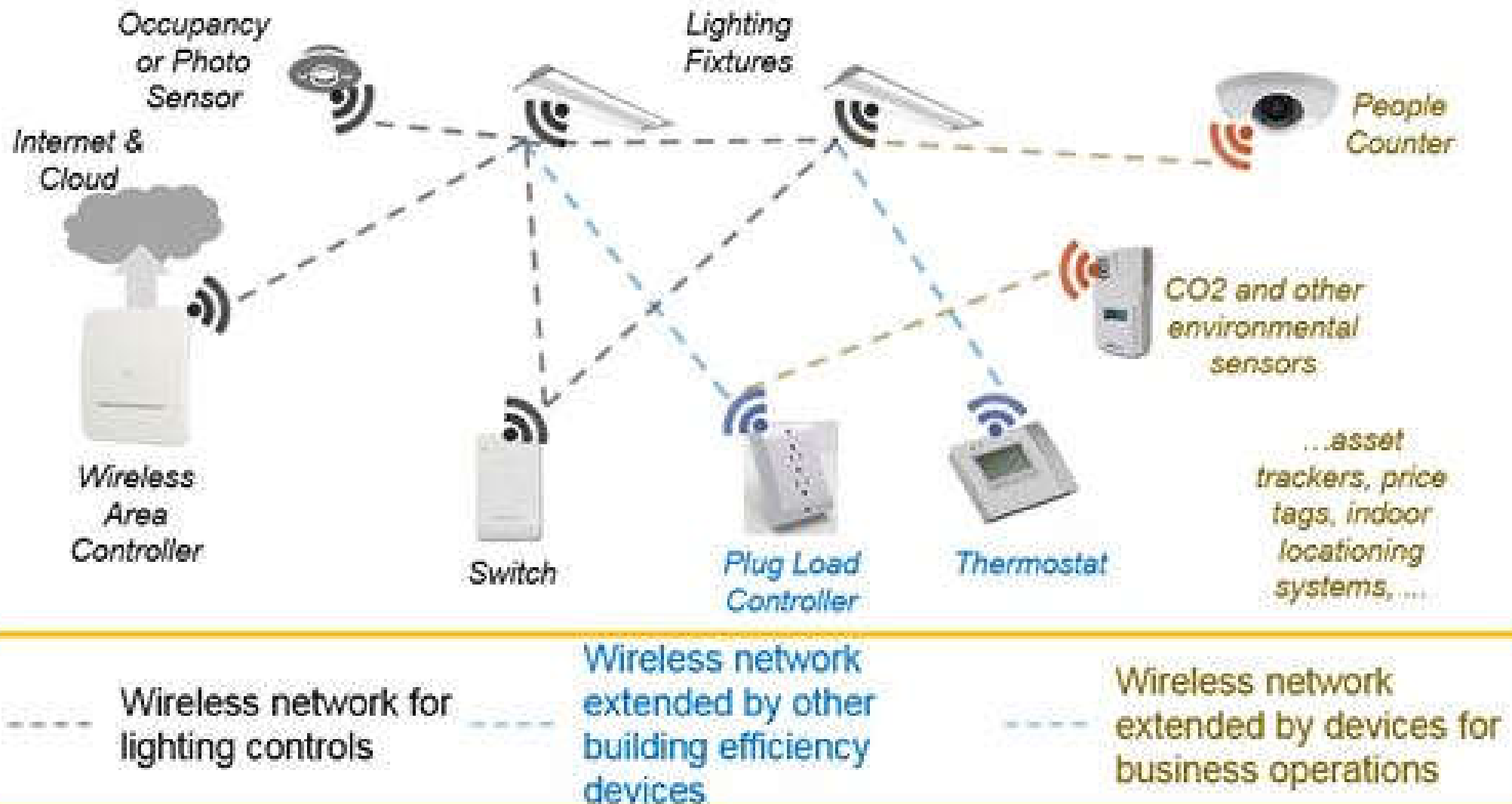
An example of wired & wireless controls for open office layout



Wireless lighting control systems



Wireless control systems for lighting, HVAC & plug loads



Wired & wireless systems



- **Digital Addressable Lighting Interface (DALI)**
 - A protocol (language) for bi-directional, digital communication between lighting-control devices
 - Technically managed in the open, global standard IEC 62386
 - DALI-2™ is the certification program based on the latest version of the DALI protocol
 - Setting standard for smart lighting control
 - Focused on interoperability



Digital Addressable Lighting Interface (DALI) & IEC 62386 standard

IEC 62386 standard

Purchase standards via the [IEC website](#)

More details on IEC 62386: [DiiA website](#)

Red text = Parts
aligned with DALI-2

Part 101: General requirements – System components

Part 102: General requirements – Control gear

*Parts 2xx: Particular requirements
for control gear*

Part 104: General requirements – Wireless and alternative wired systems

Part 105: General requirements –
Firmware update (In progress)

Part 103: General requirements – Control devices

*Parts 3xx: Particular requirements
for control / input devices*

Published:

Part 201: Fluorescent lamps

Part 202: Self-contained emergency lighting
Part 203: Discharge lamps (excluding fluorescent lamps)
Part 204: Low voltage halogen lamps
Part 205: Supply voltage controller for incandescent lamps
Part 206: Conversion from digital signal into DC voltage

Part 207: LED modules

Part 208: Switching function
Part 209: Colour control

Published:

Part 216: Load referencing
Part 217: Thermal gear protection
Part 218: Dimming curve selection
Part 220: Centrally-supplied DC emergency operation
Part 221: Load shedding
Part 222: Thermal lamp protection
Part 224: Integrated light source

Published:

Part 301: Push buttons
Part 302: Absolute input devices
Part 303: Occupancy sensors
Part 304: Light sensors
Part 332: Input control devices - Feedback
Part 333: Manual configuration

In progress:

Part 305: Colour sensor

DiiA creates DALI-2 Test Procedure specifications based on these individual Parts of IEC 62386, enabling DALI-2 certification.

Wired & wireless systems



- Digital Addressable Lighting Interface (DALI)

- A 2-wire bus is used for communication (commands/data) & for power to some devices



- Commands allow control, configuration & querying of the products

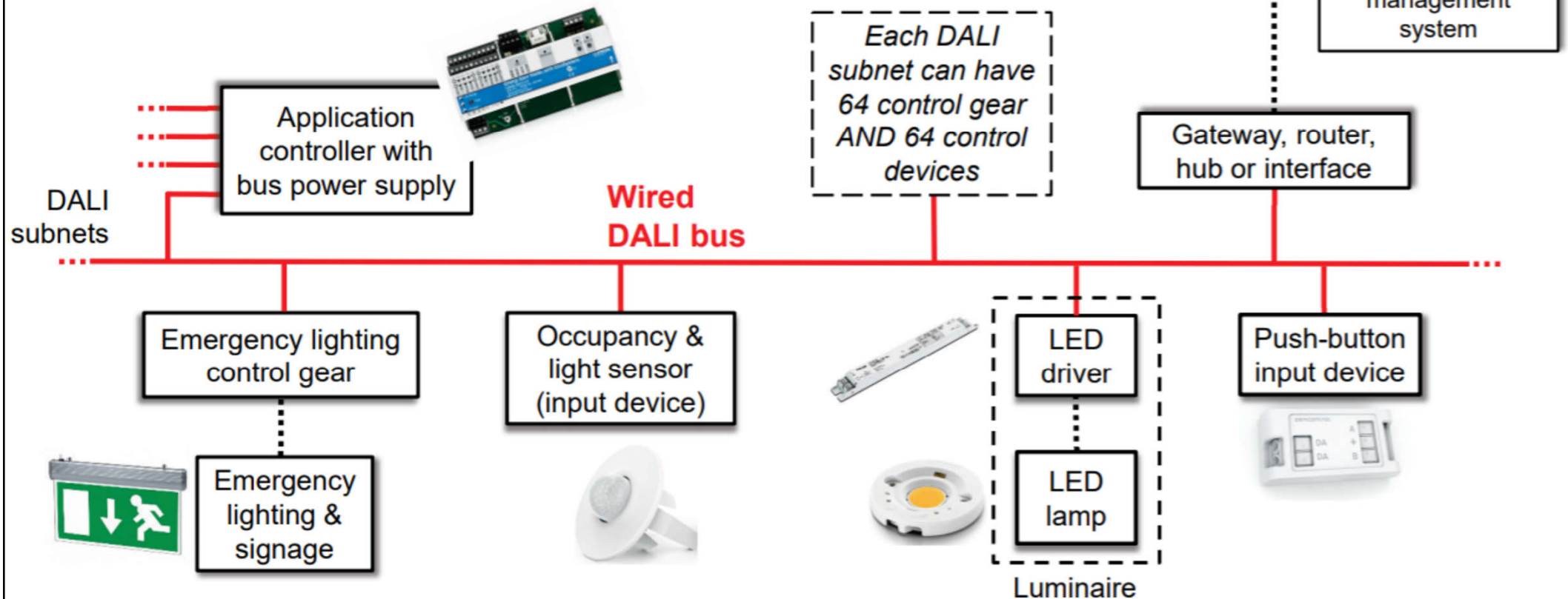


- Commands can be addressed to individual devices, to a group of devices, or broadcast to all devices

- Scenes allow fast & efficient recall of light levels across the system

- DALI devices: bus power supplies, control gear, control devices

DALI lighting-control system example



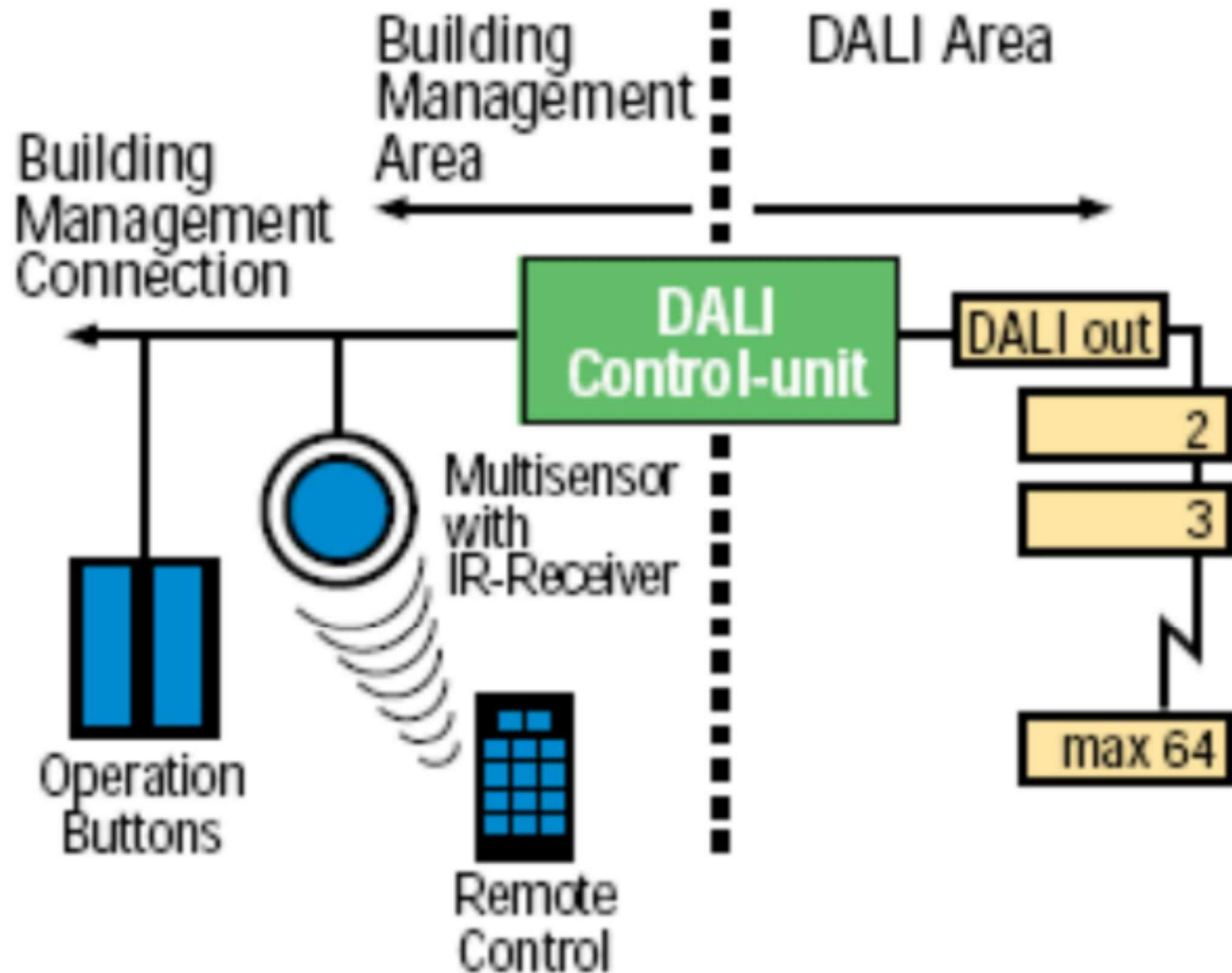
The DALI bus carries DALI power & data on the same pair of wires. Each DALI subnet can have 64 control gear & 64 control devices. Control gear provide power to LEDs & other light sources. Control devices include application controllers (which make decisions & send commands), and input devices such as sensors, switches & push-button devices. A bus power supply is required, providing up to 250 mA and typically 16V to the DALI bus.

Wired & wireless systems



- What can DALI do?
 - Digital control of light with intelligent feedback
 - Precise, repeatable light-output control & standardized dimming curve
 - Occupancy & light-level sensing
 - Luminaire, energy & diagnostics data (for monitoring)
 - Emergency lighting, automated tests (safety)
 - Colour control for human-centric-lighting (well-being)
 - Participate in the Internet of Things (IoT)
 - Connectivity via wireless & IP-based networks

DALI system as a pure subsystem of the BAS/BMS



Wired & wireless systems



- D4i – the DALI standard for intelligent, IoT-ready luminaires
 - DALI-2 power-supply & data specifications
 - D4i LED drivers & sensors provide luminaire, energy & diagnostics data
 - For performance monitoring, asset management, predictive maintenance & many other tasks
 - Enables intra-luminaire DALI (smart connection)
 - Simplify addition of sensors & communication devices to luminaires



DALI data & D4i: An outdoor street lighting example



In the factory:

Luminaire data is programmed into drivers.

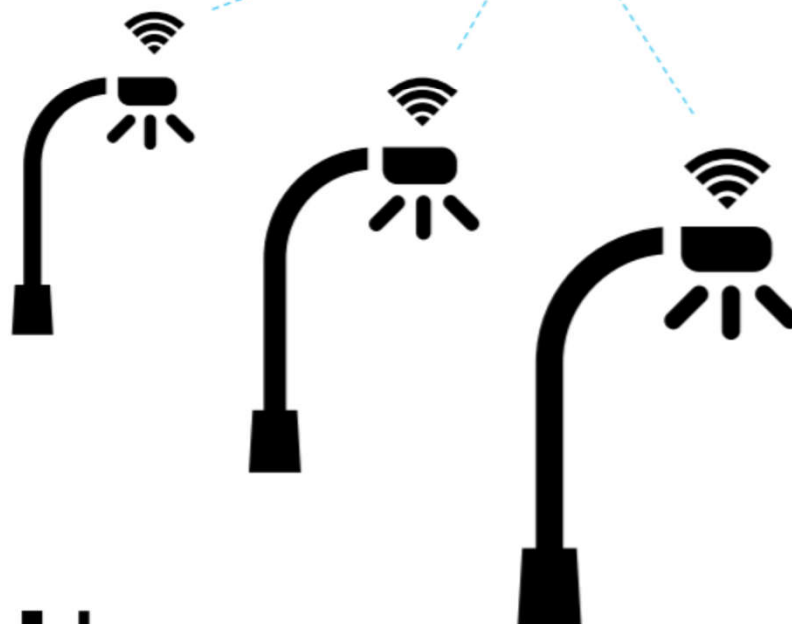
During operation:

Performance monitoring

- Energy usage data can be used e.g. for billing



Network



In the field:

Automated commissioning

- When installed, luminaire can automatically transfer data to remote network
- Reduces human error, saves installation time and cost
- Operator has a full map of asset information

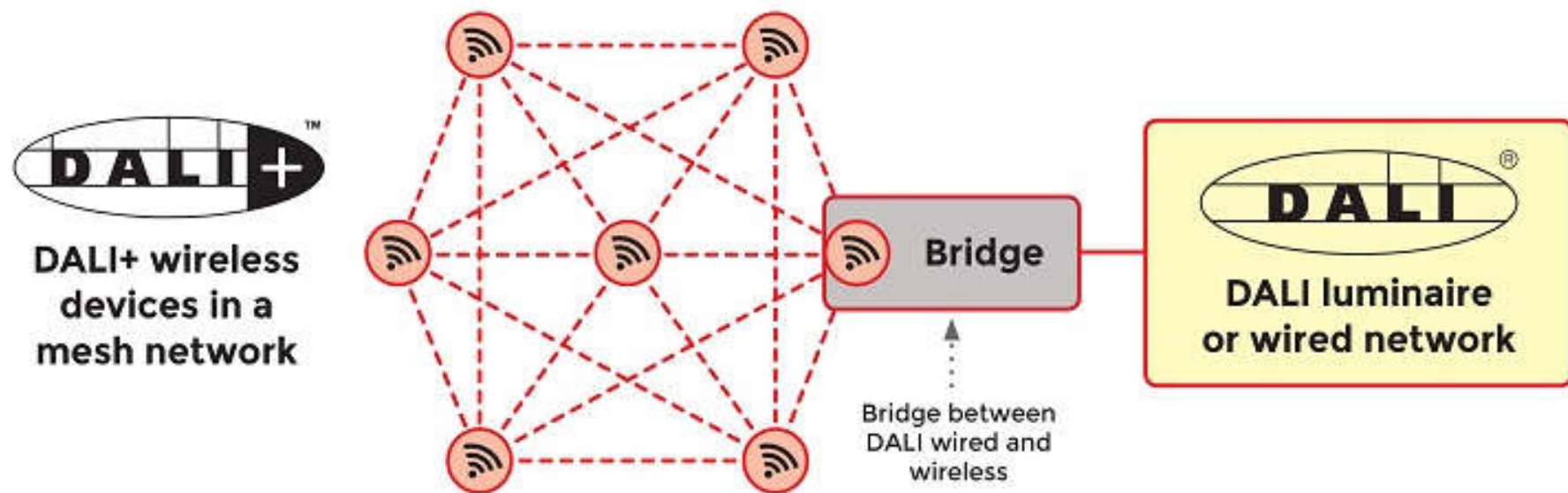
During operation:

Predictive maintenance

- Diagnostics data allows network operator to anticipate need for maintenance
- Repair team has knowledge of location and type of fixture



DALI lighting control plus wireless & IP-based networking



(Source: DALI Alliance (Digital Illumination Interface Alliance, or DiiA) <https://www.dali-alliance.org/>)

Smart lighting systems



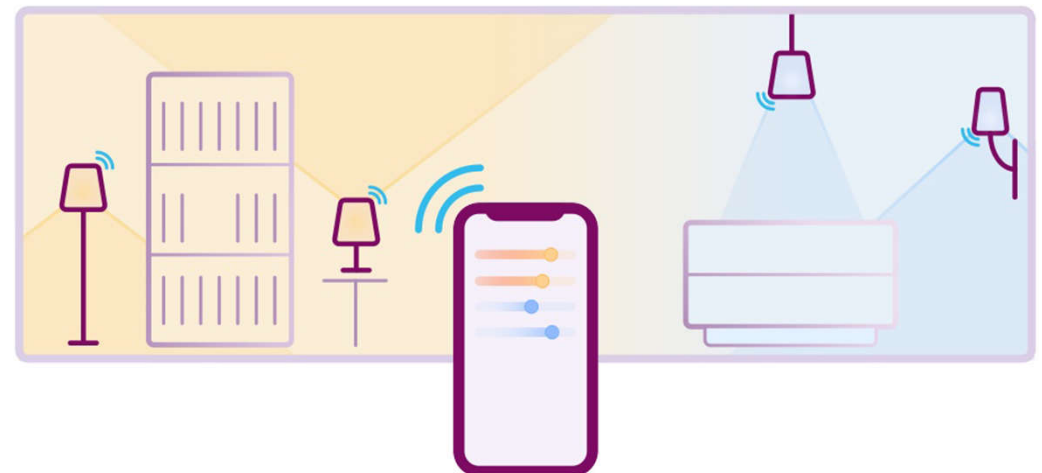
- Typical functions of smart lighting systems:
 - Control lights on mobile Apps
 - Smart schedules & sensing
 - Voice control with smart assistant devices
- Communication technologies used:



- Wi-Fi
- Bluetooth
- Zigbee/Z-Wave
- LoRa



zigbee

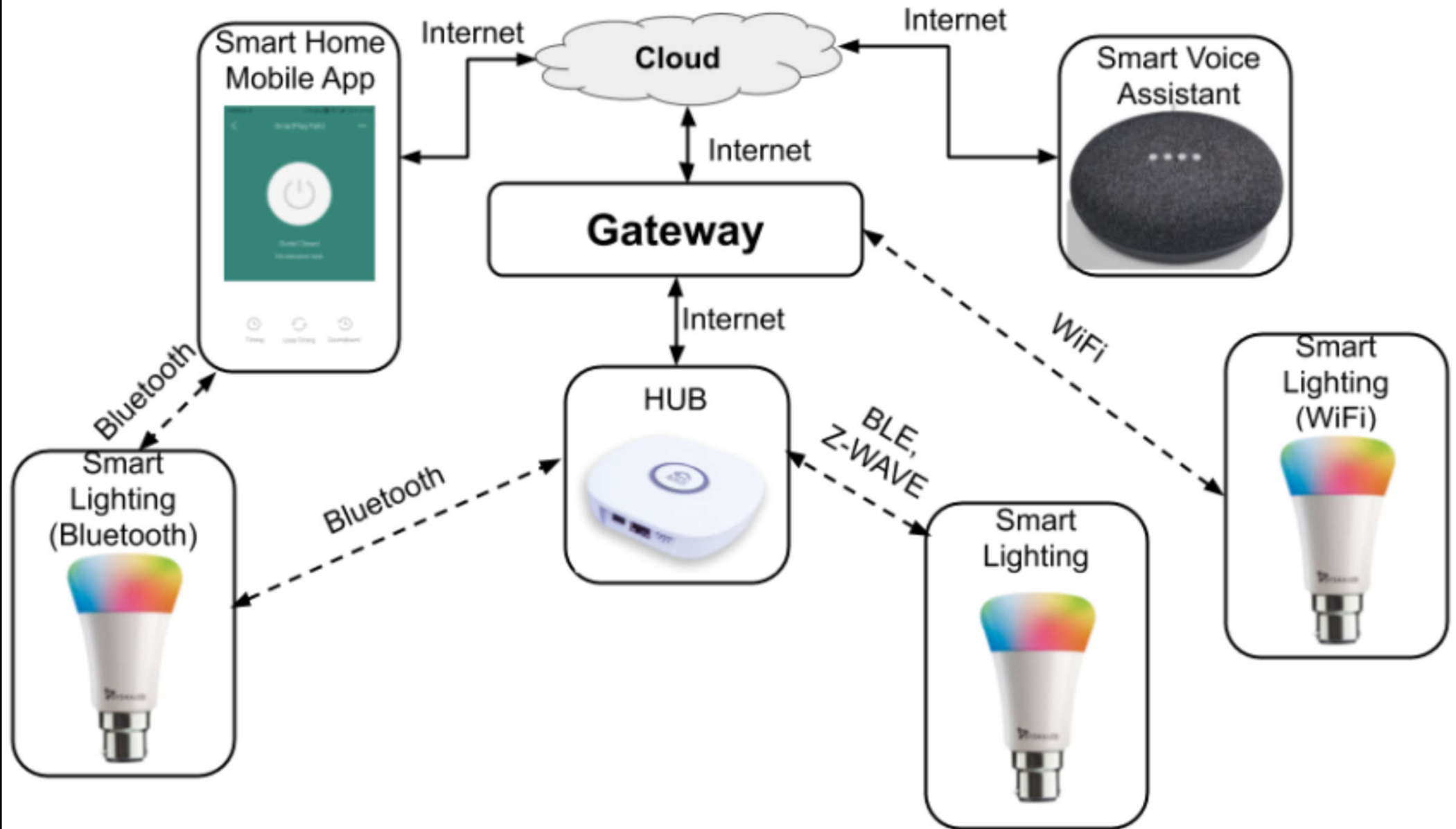


Smart light bulbs controlled by a mobile app or an IoT gateway

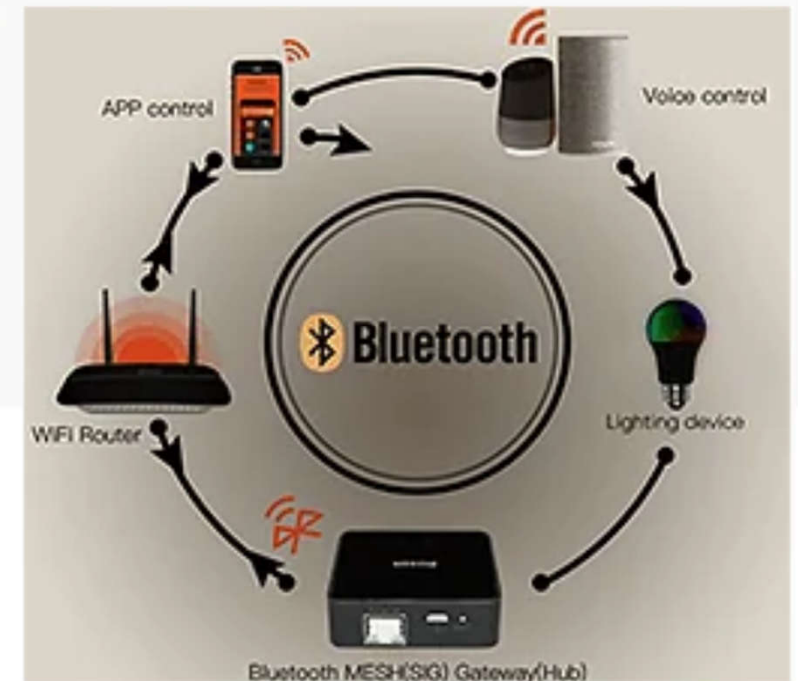
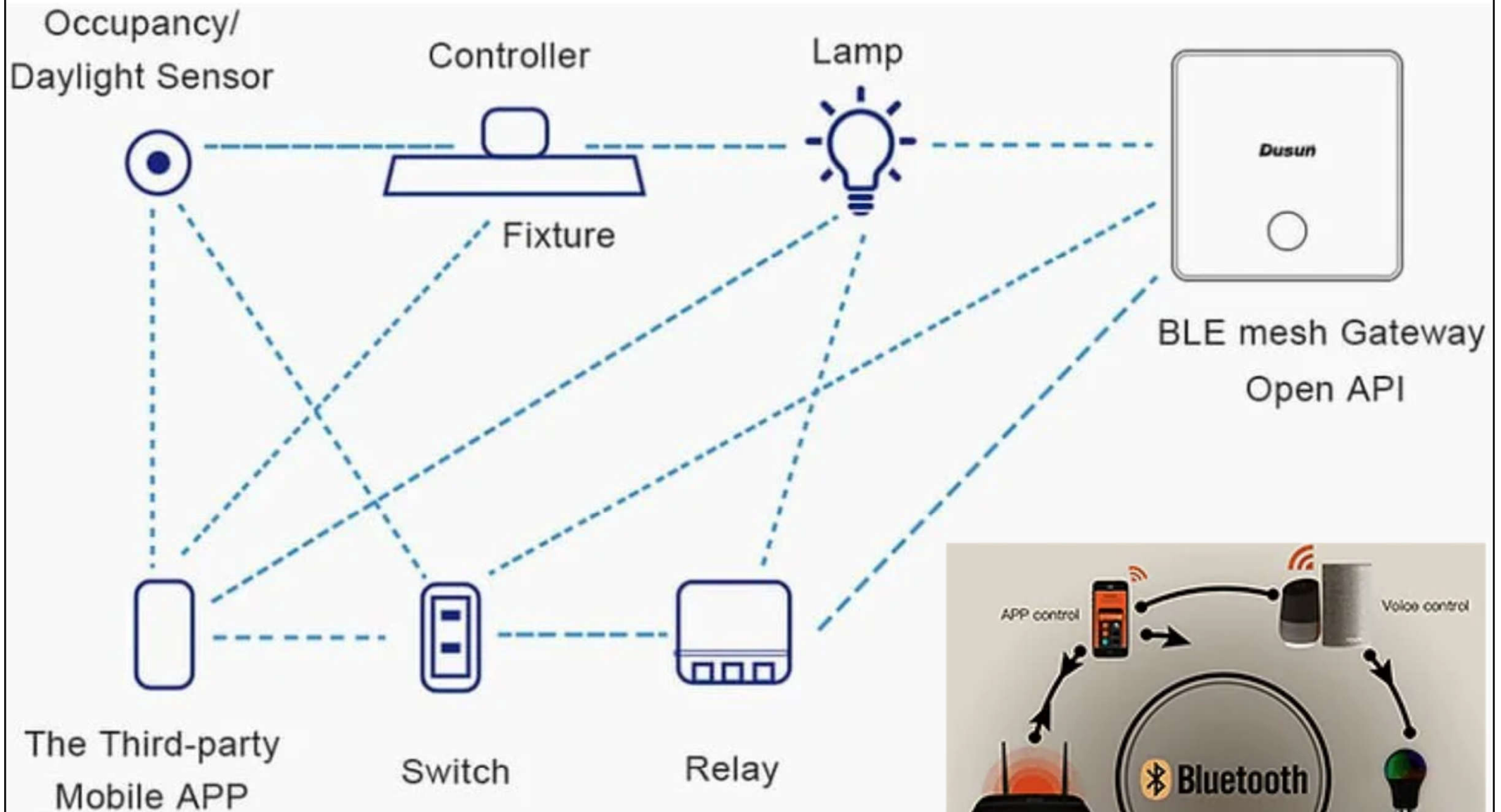


(Source: <https://www.dusuniot.com/blog/how-to-using-iot-in-smart-lighting/>)

Smart lighting using smart home mobile Apps & smart voice assistant



Basic concept of smart lighting control system



Smart lighting control solutions



(Source: <https://www.dusuniot.com/solution/ble-mesh-lighting-control-solution/>)



Smart lighting systems

- Typical applications of smart lighting:
 - Interior lighting in offices & residential buildings
 - Outdoor lighting in public streets & roads
- Main characteristics:
 - Improved light quality & energy efficiency
 - Use of light emitting diode (LED) technology
 - Sensor-based lighting
 - Human centric lighting (HCL)
 - Visible light communication (VLC)

Smart lighting for commercial office buildings

Meeting Room

Workplace



Light Control



Blind Control



Scene Setting



Occupancy Response



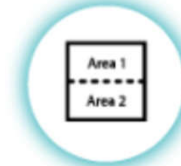
A/V Integration



Scheduling



Daylight Harvesting



Zoning



Management System

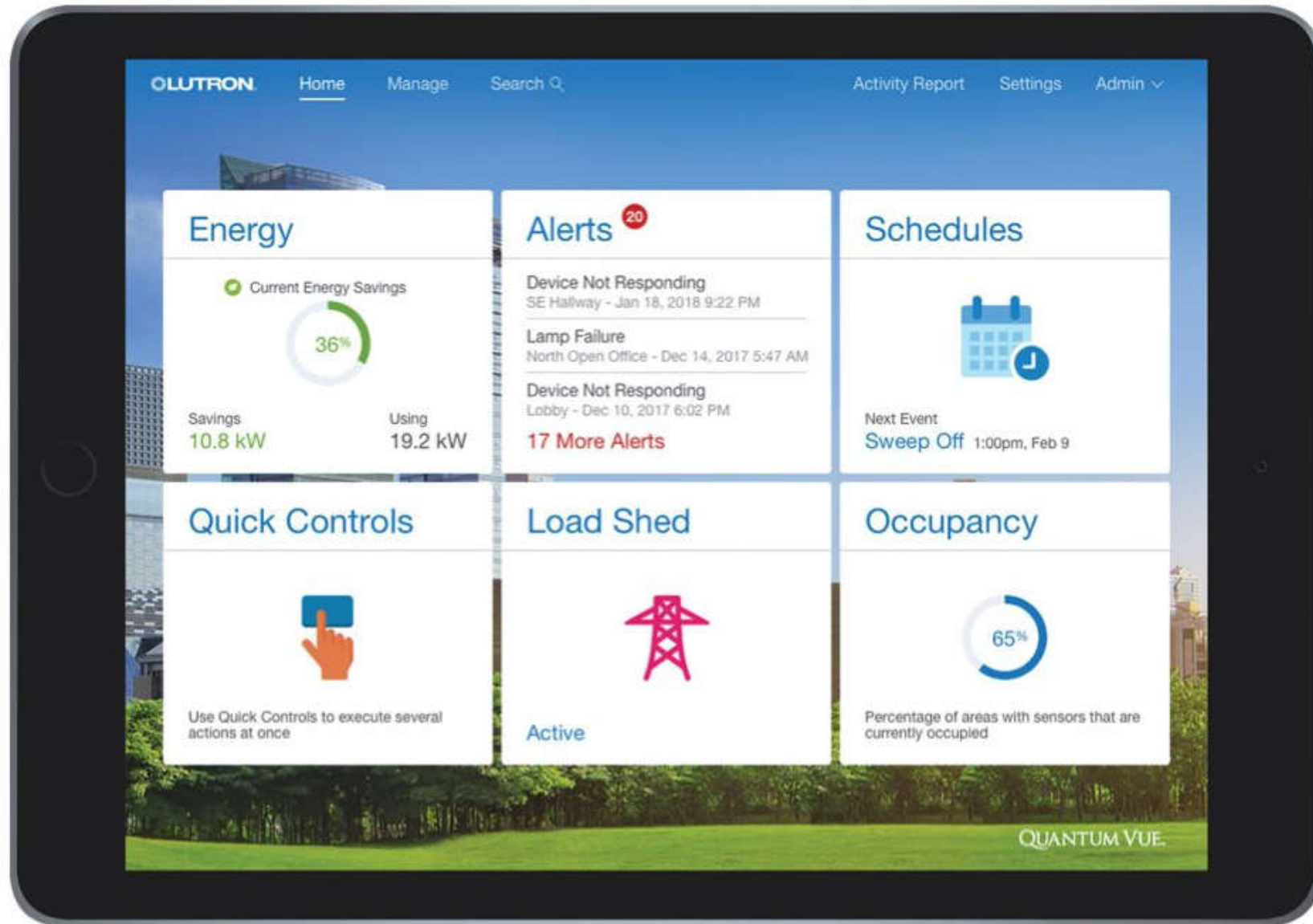




Smart lighting systems

- Smart lighting for commercial office buildings
 - 1. Preset scene control: e.g. presentation, films
 - 2. Occupancy response: adjust or on/off, zoning
 - 3. Daylight control: daylight harvesting, glare
 - 4. Scheduling: change with preset schedule
 - 5. Human centric lighting (HCL) control
 - 6. App control: on mobile phone or tablet
 - 7. Application programming interface (API)
 - 8. BAS/BMS integration

Lighting control software (web-based) with a dashboard management

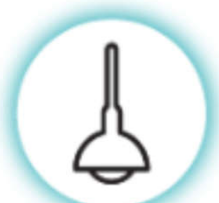


Video: Quantum Vue – Facility Management Software (1:18)

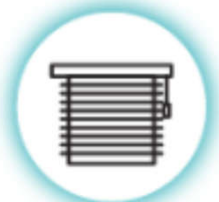
<https://youtu.be/dLNdG6ndLcY>

(Source: <https://commercial.lutron.com/us/en/whole-building-systems/quantum>)

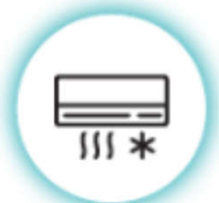
Smart lighting for residential buildings



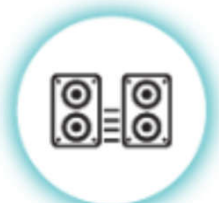
Light Control



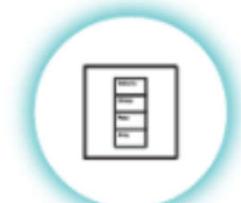
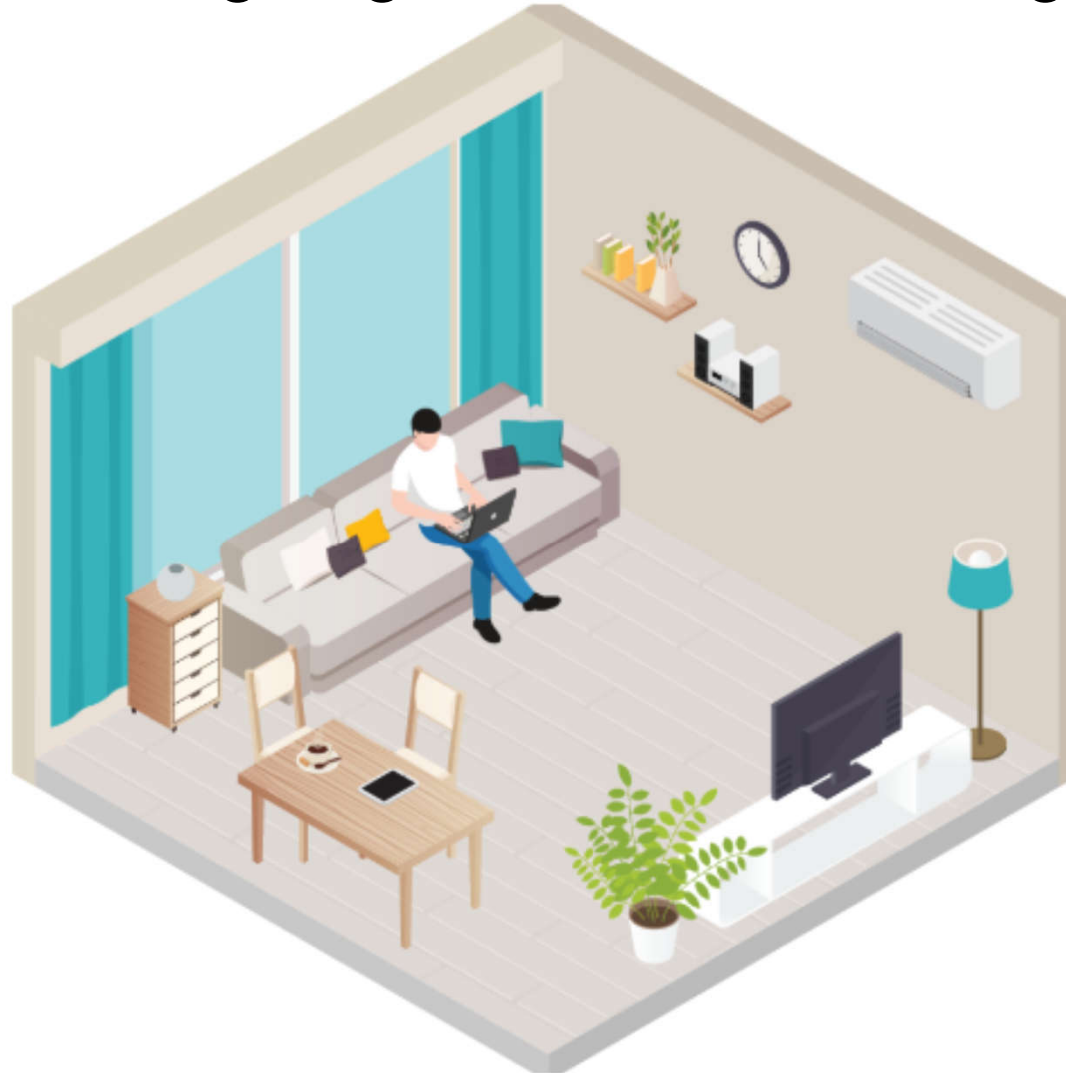
Blind Control



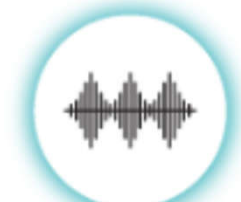
HVAC Control



A/V Control



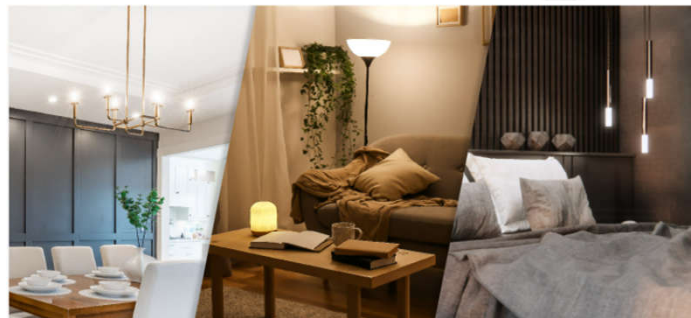
Scene Setting



Voice Control



Geofencing





Smart lighting systems

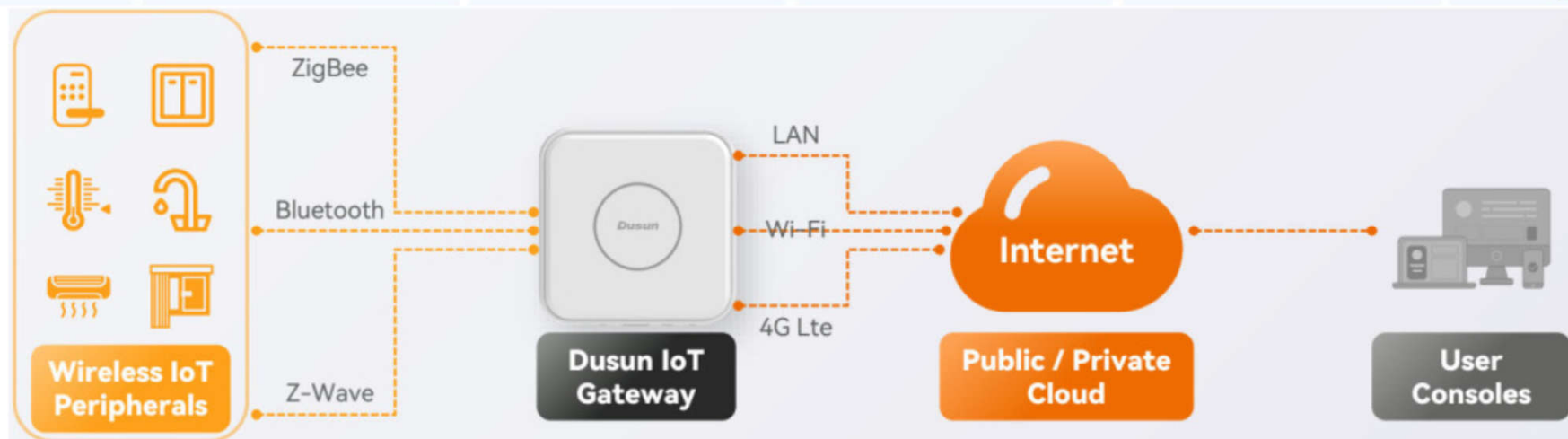
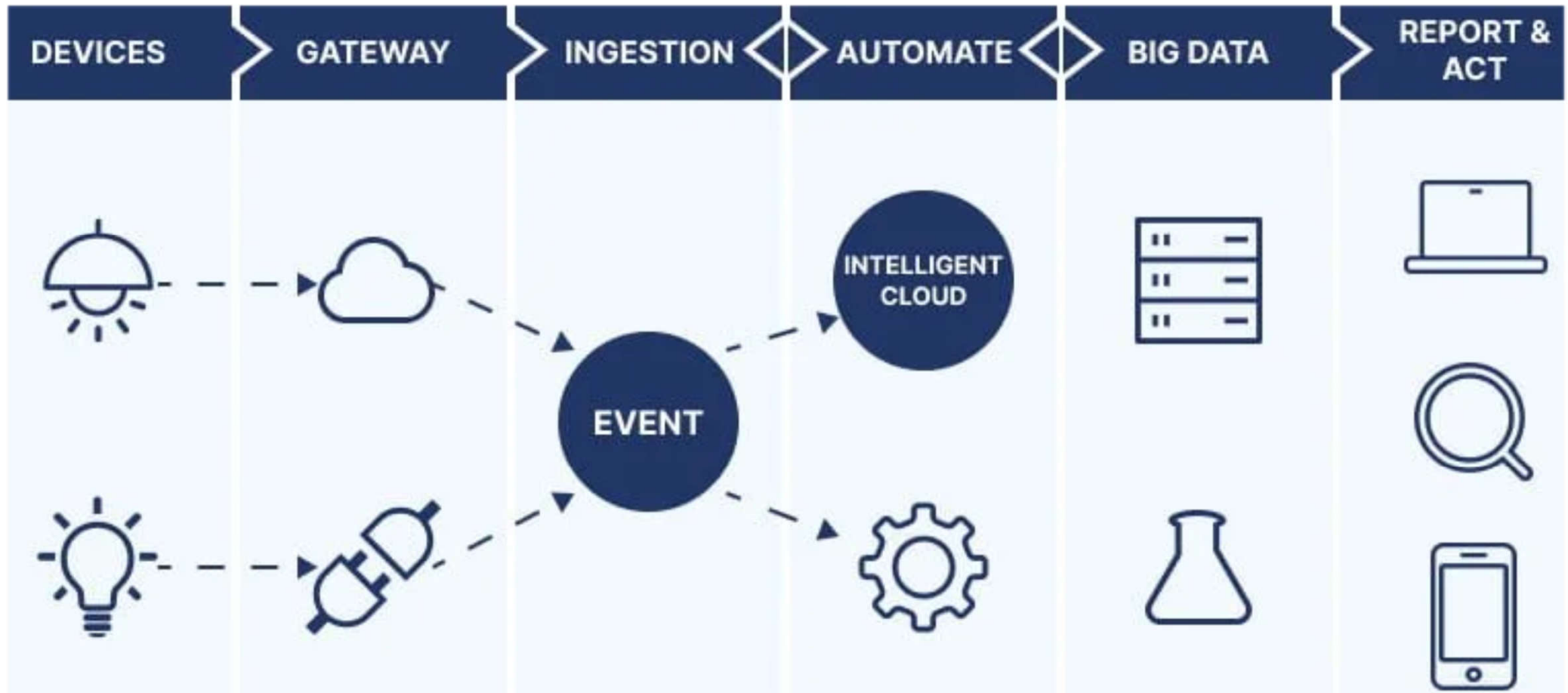
- Smart lighting for residential buildings
 - 1. Light control: e.g. set lighting moods & colour
 - 2. Blind control: control daylight & glare
 - 3. Temperature control: adjust HVAC systems
 - 4. Audio visual (AV) control: for AV equipment
 - 5. App control: on mobile phone or tablet
 - 6. Voice control: voice activation/commands
 - 7. Integration with home automation system

Sensor-based lighting (sensing of motion/ambient daylight)

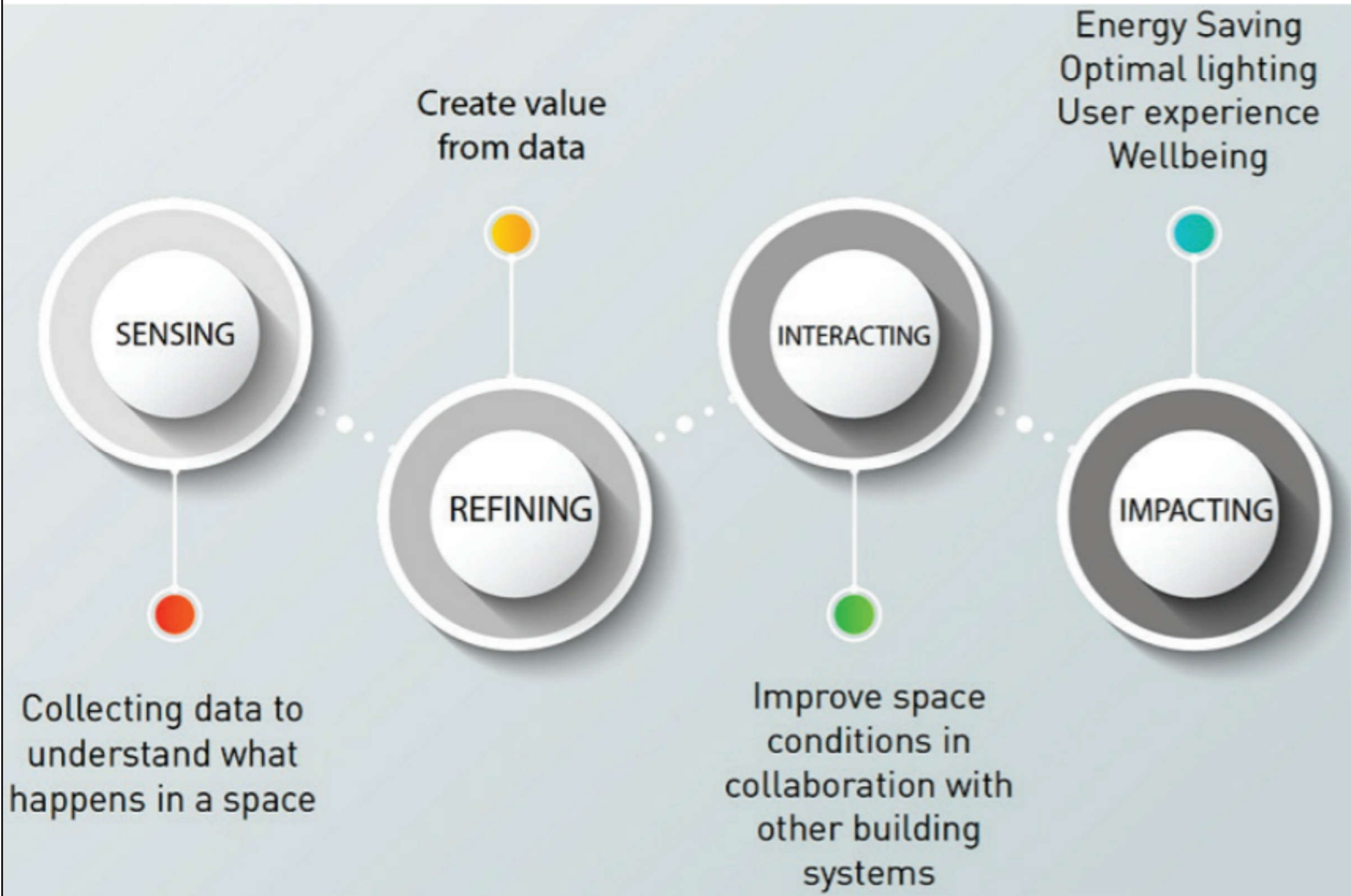


(Source: <https://www.dusuniot.com/blog/how-to-using-iot-in-smart-lighting/>)

Integrate Internet of Things (IoT) gateway with smart lighting



Elements of lighting intelligence

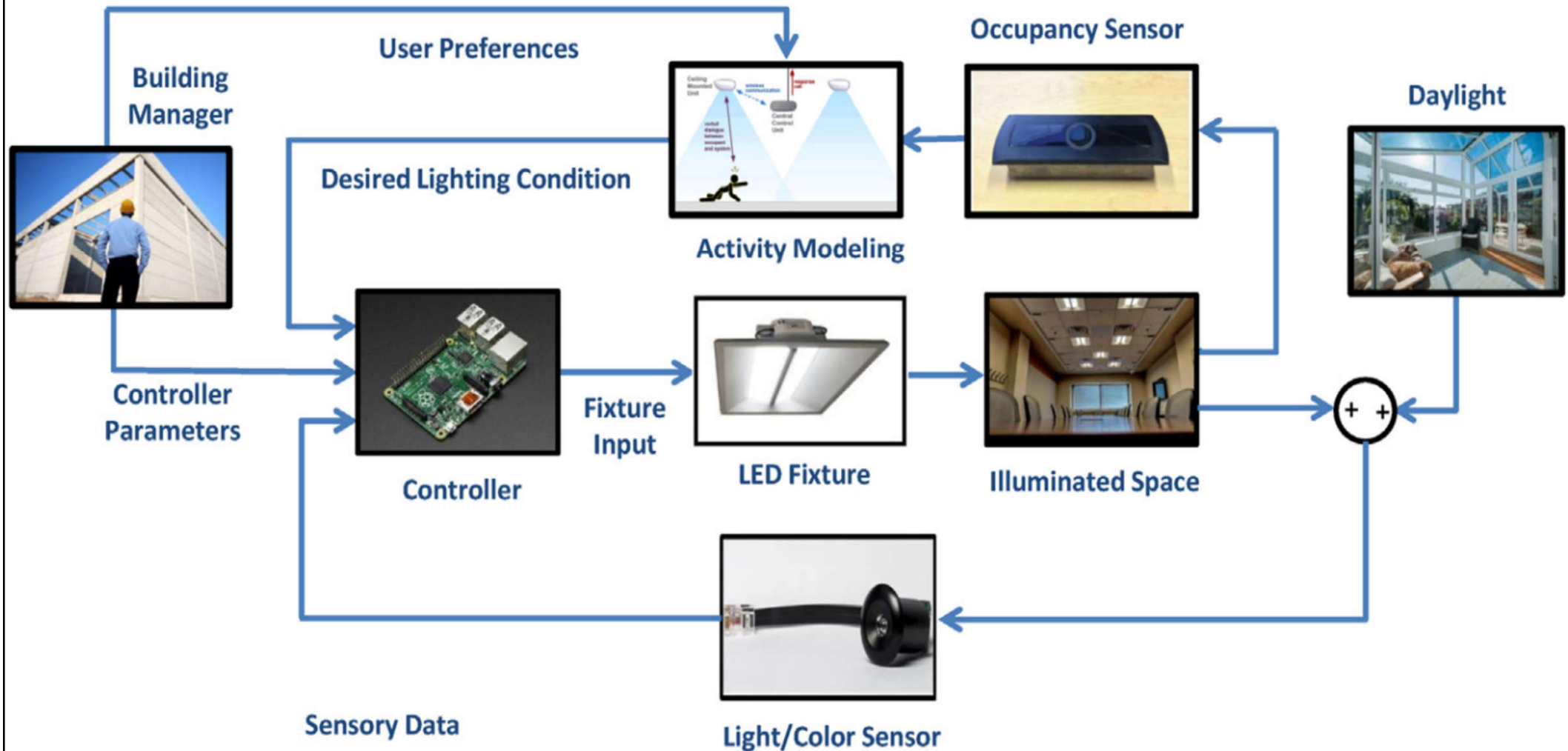




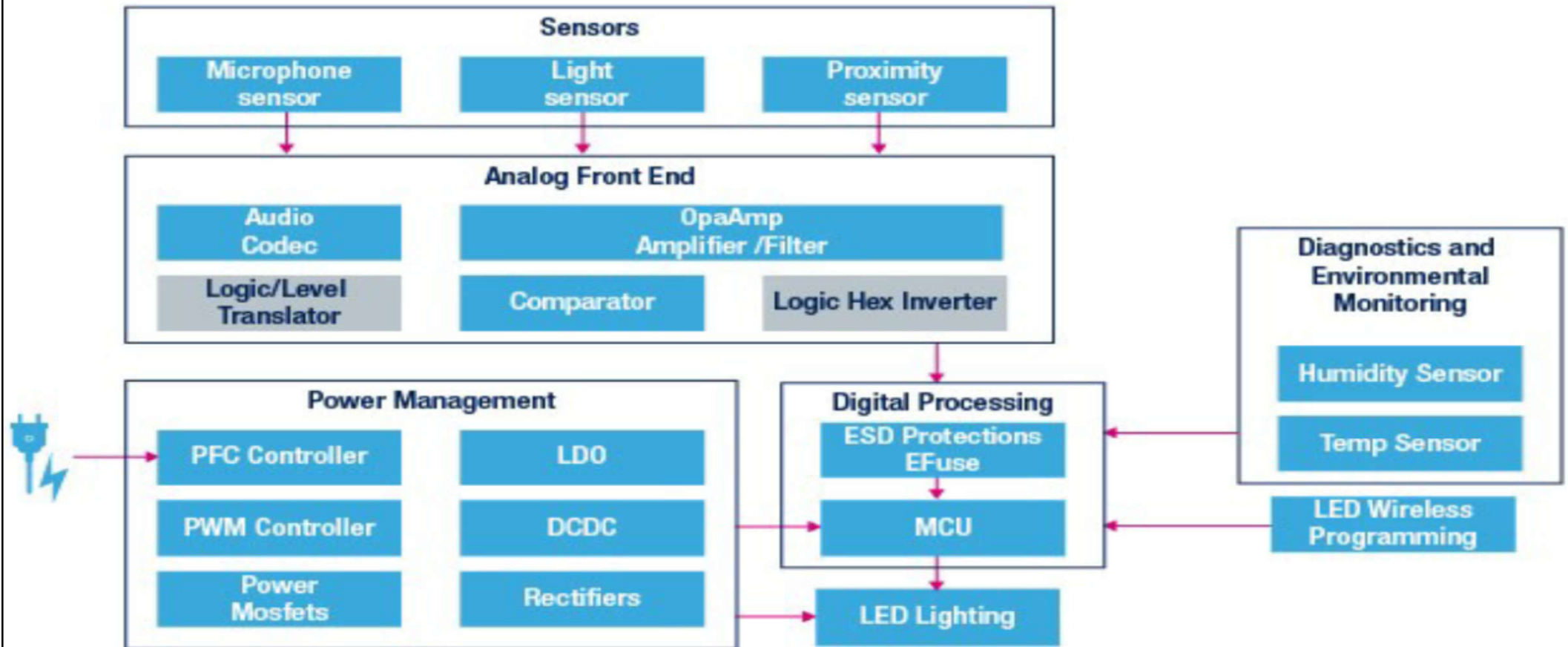
Lighting intelligence

- Feedback control of lighting systems
 - Logic-based controllers
 - Decision-making techniques are used to infer the correct action for the lighting system in different situations based on measured values from the sensors
 - Regulation-based controllers
 - Aim to achieve closed-loop stability while guaranteeing that the generated illumination tracks a predetermined reference or setpoint value
 - Optimization-based controllers (solve the optimization problem)

Feedback control loop in a smart lighting system



Sensor technologies embedded in smart lighting

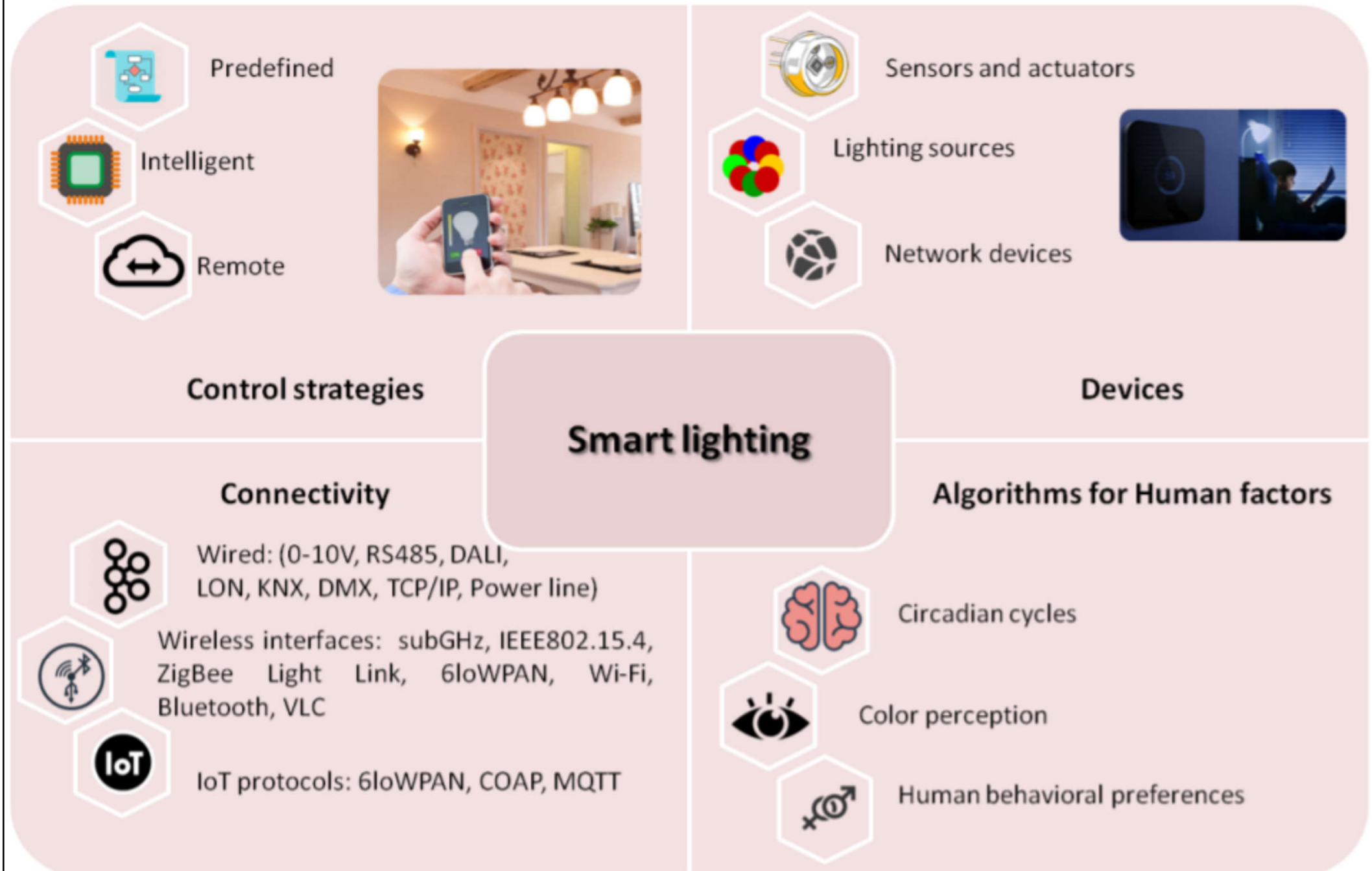




Lighting intelligence

- **Connected smart lighting**
 - Lighting installations in which the luminaires, with integrated sensors, are interconnected in a wired or wireless network to both control & monitor the lighting
 - Microcontrollers & many sensors, like light, occupancy, temperature, humidity & noise sensors, are small enough to be incorporated in a luminaire
 - In this way, the luminaire becomes both a source of light & information (data)

Key elements for smart lighting systems

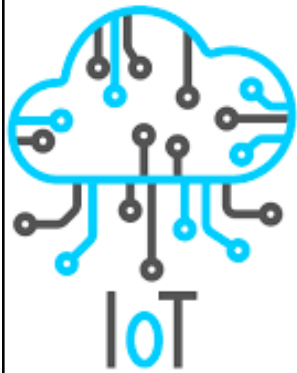




Lighting intelligence

- Light beyond illumination

- By connecting a network of LED luminaires with integrated sensors to a network, it becomes the backbone of the **Internet of Things (IoT)**

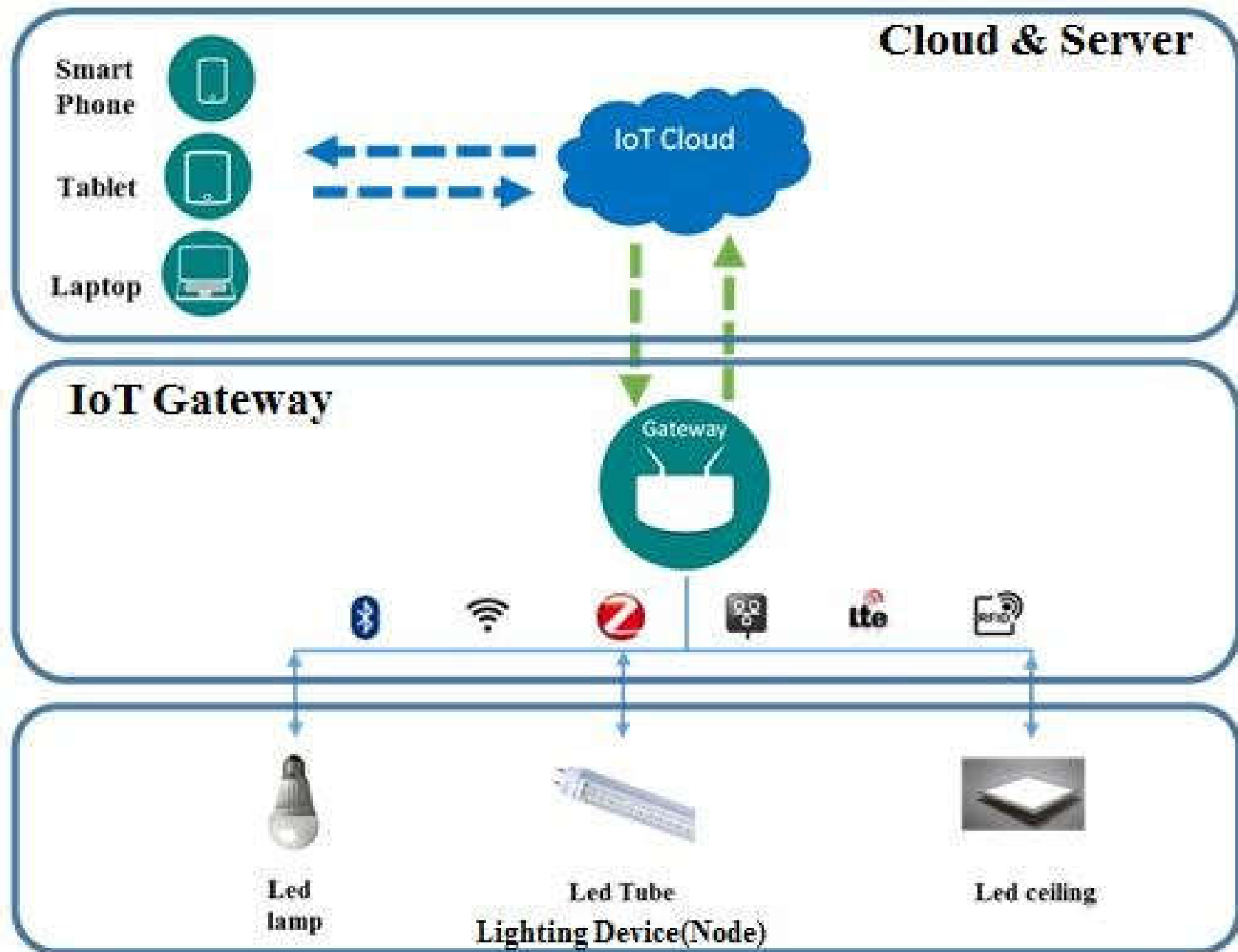


- For smart actions of the connected building services installations (e.g. lighting, HVAC) & facility management (e.g. automated cleaning & maintenance)

- Light from LED luminaires can be used simultaneously for lighting & wireless data transfer -> **Visible Light Communication (VLC)**



Internet of Things (IoT) connected lighting system

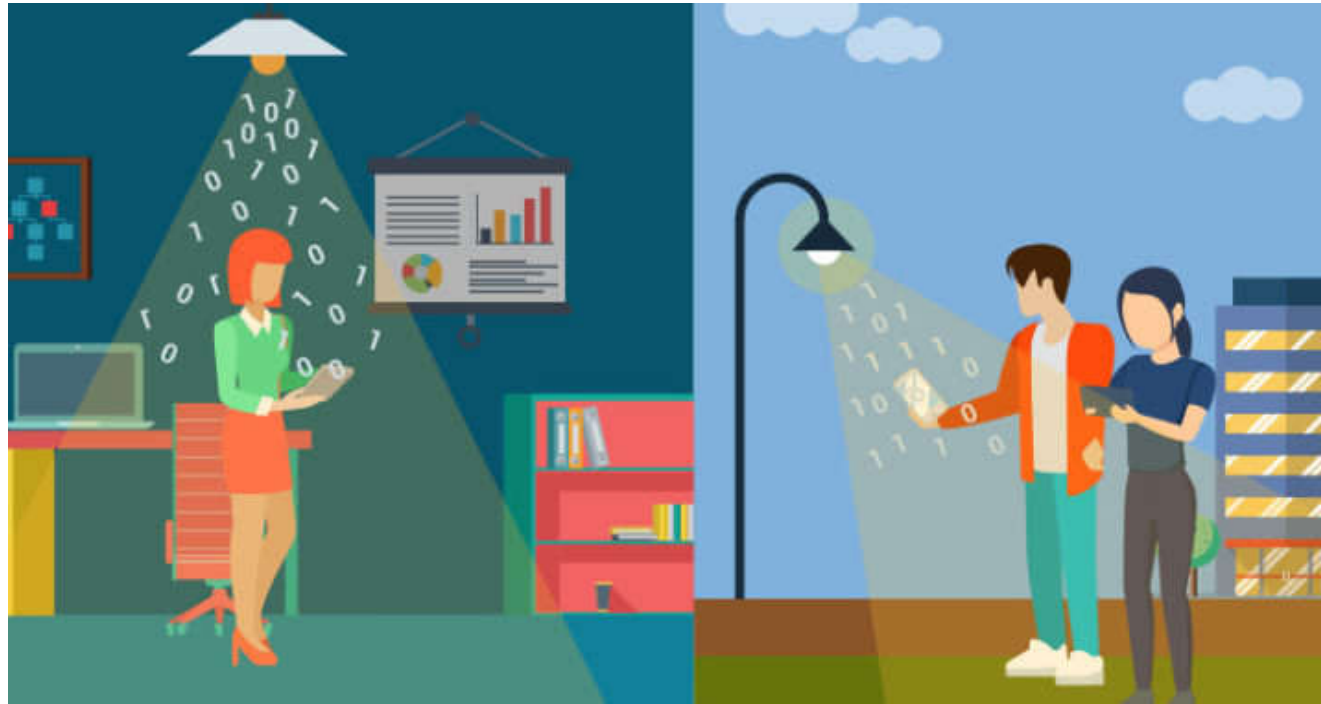




Lighting intelligence

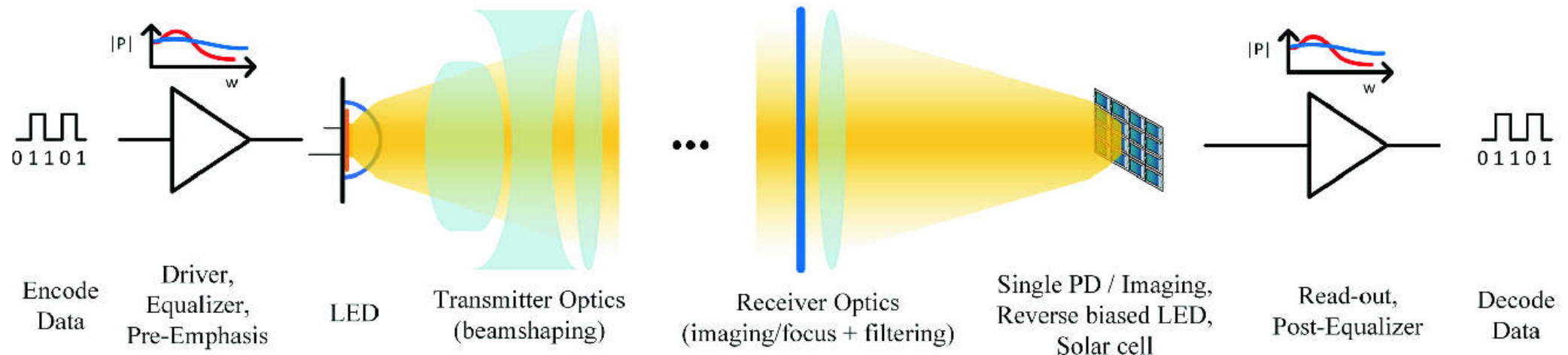
- Smart lighting & Internet of Things (IoT)
 - Light points can serve as the infrastructure for IoT systems (both indoor & outdoor)
 - Smart sensor networks & connectivity
- Visible Light Communication (VLC)
 - Low power consumption, easy installation, high security, no electromagnetic interference
 - Potential uses: indoor positioning, scanning sensor, light fidelity (Li-Fi) as alternative to WiFi network

Principles of Visible Light Communication (VLC)



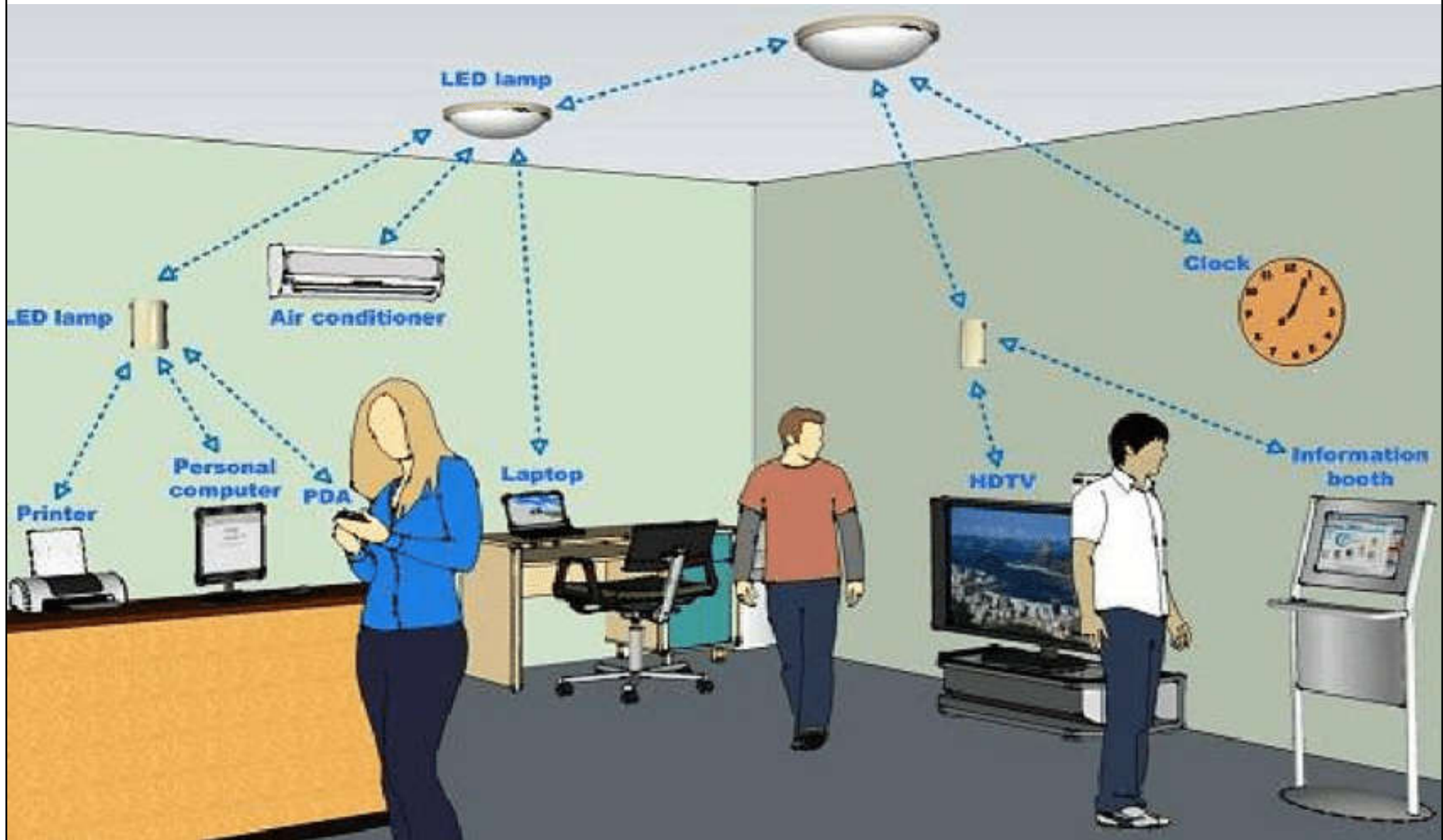
Transmitter

Receiver



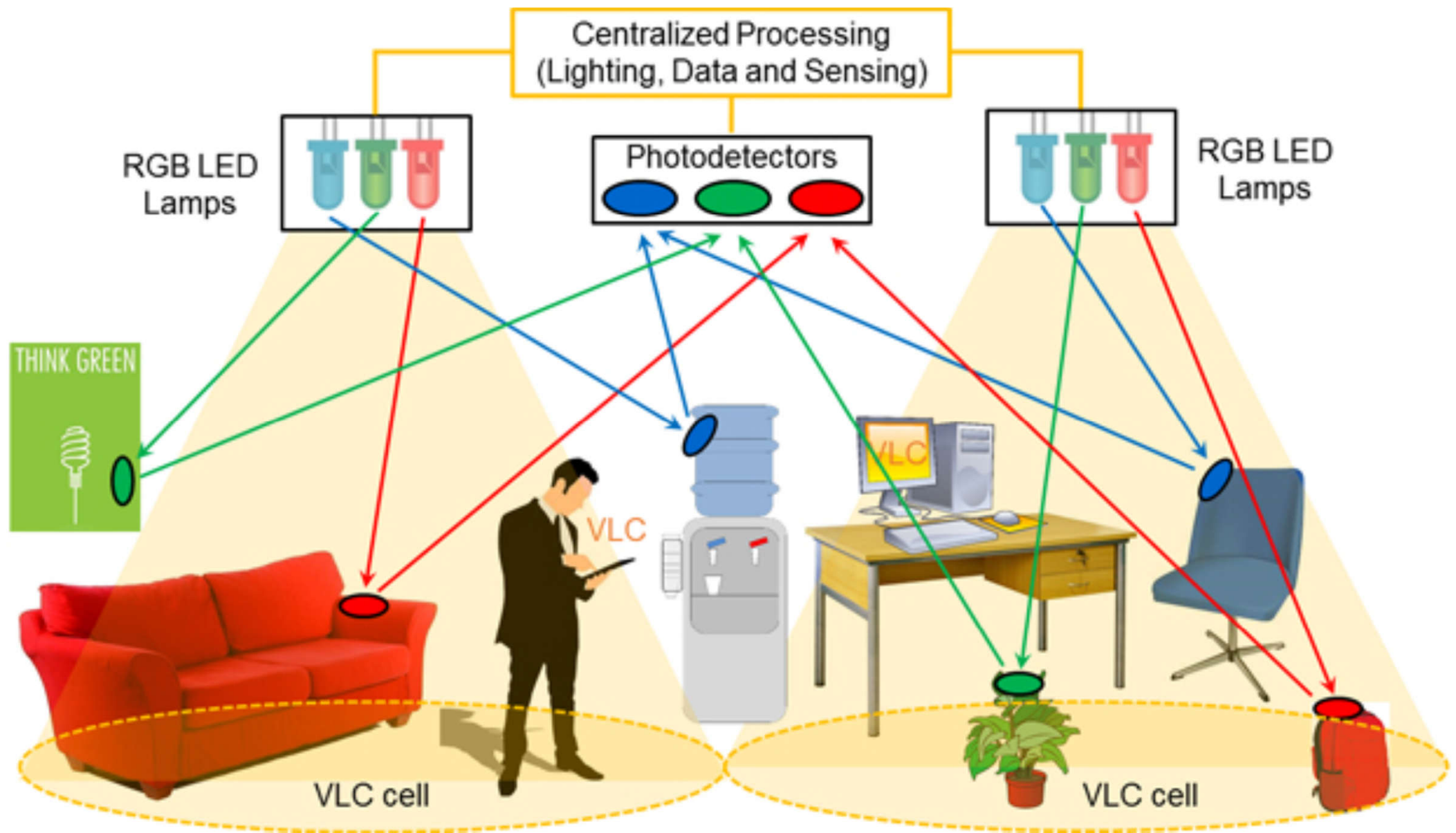
(Source: <https://enlightem.eu/a-tutorial-on-visible-light-communication-an-academic-and-industrial-perspective/>;
https://link.springer.com/chapter/10.1007/978-3-030-24892-5_8)

Visible Light Communication (VLC) environment & data transmission



(Source: Gabr M. I., 2016. Data transmission via visible light communication (VLC) technique, *International Journal of Innovative Research in Science, Engineering and Technology*, 5 (9) 16473-16481. <https://doi.org/10.15680/IJIRSET.2016.0509133>)

Visible light communication for indoor monitoring





Further reading

- Introduction to Lighting Controls
<https://lightingcontrolsassociation.org/2017/07/21/introduction-to-lighting-controls/>
- Introduction to Wireless Lighting Controls
<https://lightingcontrolsassociation.org/2018/03/23/introduction-to-wireless-lighting-controls/>
- What is Smart Lighting Technology
<https://www.smlease.com/entries/automation/what-is-smart-lighting-technology/>
- Smart lighting systems for various applications
<https://www.patent-art.com/knowledge-center/smart-lighting-systems-for-various-applications/>