

MEBS6005 Building Automation Systems

<http://ibse.hk/MEBS6005/>



Internet Technologies



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Internet technologies are affecting the whole world & every one of us.

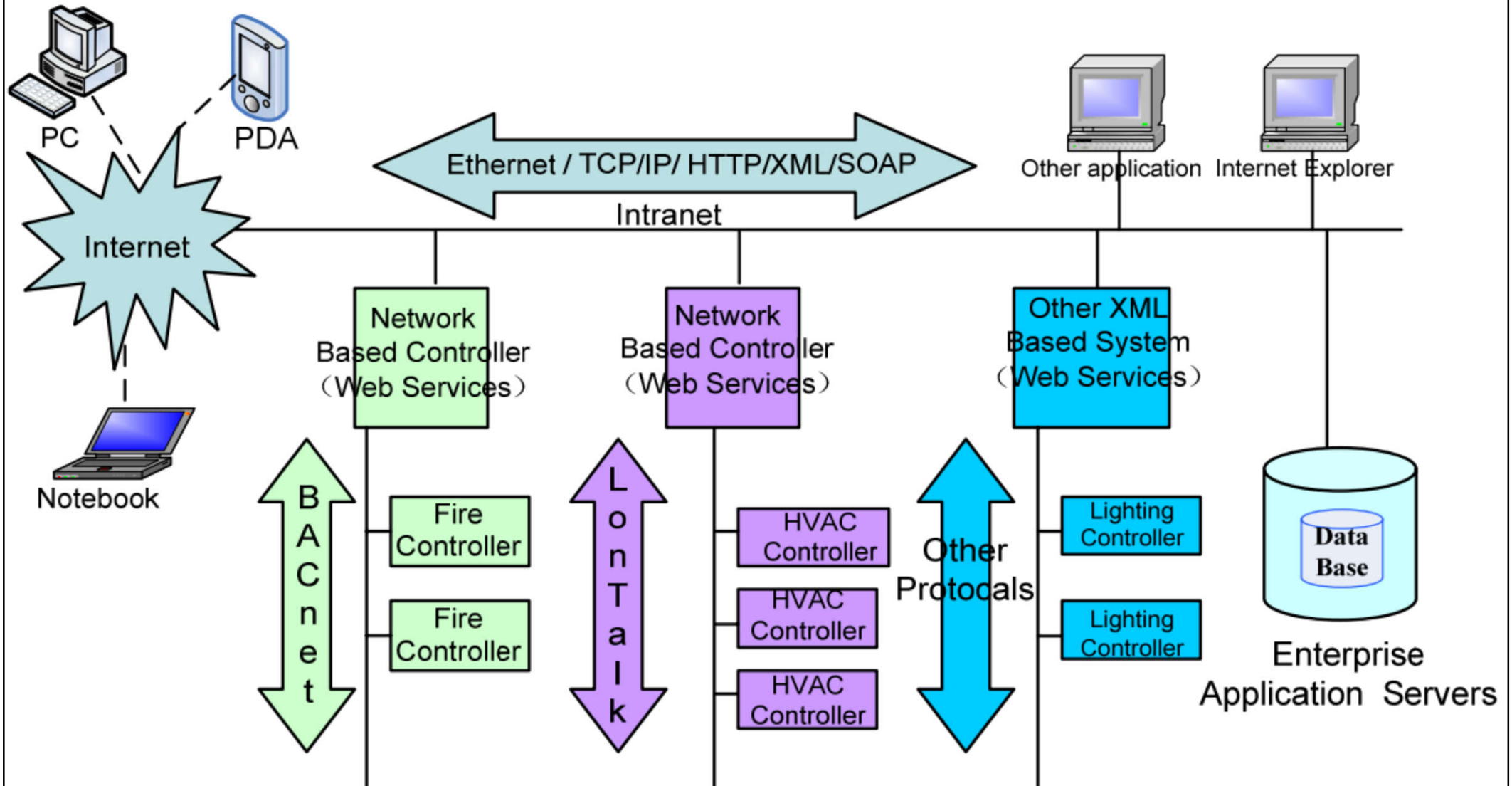


Basic concepts



- Integrating Internet technologies with BAS allows for a more seamless & efficient management of building systems & facilities
 - Enable the integration of various devices & systems of the building to create a unified network that can be monitored & controlled remotely
 - With a unified network of devices & systems, building managers can optimize the performance of their buildings & respond quickly to any issues that may arise, even remotely

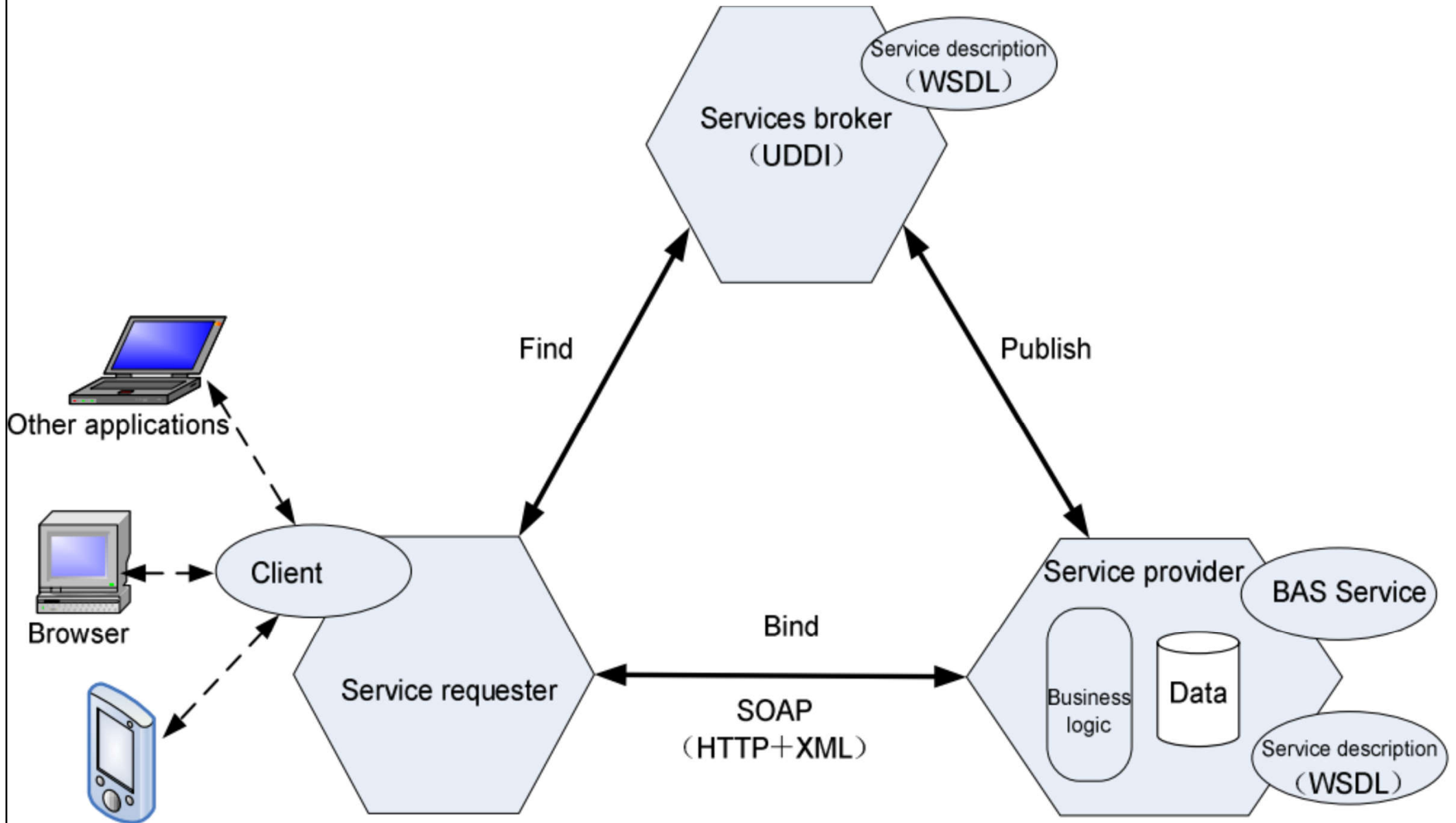
Integration between BAS & enterprise applications based on Web Services



TCP/IP = Transmission Control Protocol / Internet Protocol
 HTTP = HyperText Transfer Protocol

XML = Extensible Markup Language
 SOAP = Simple Object Access Protocol

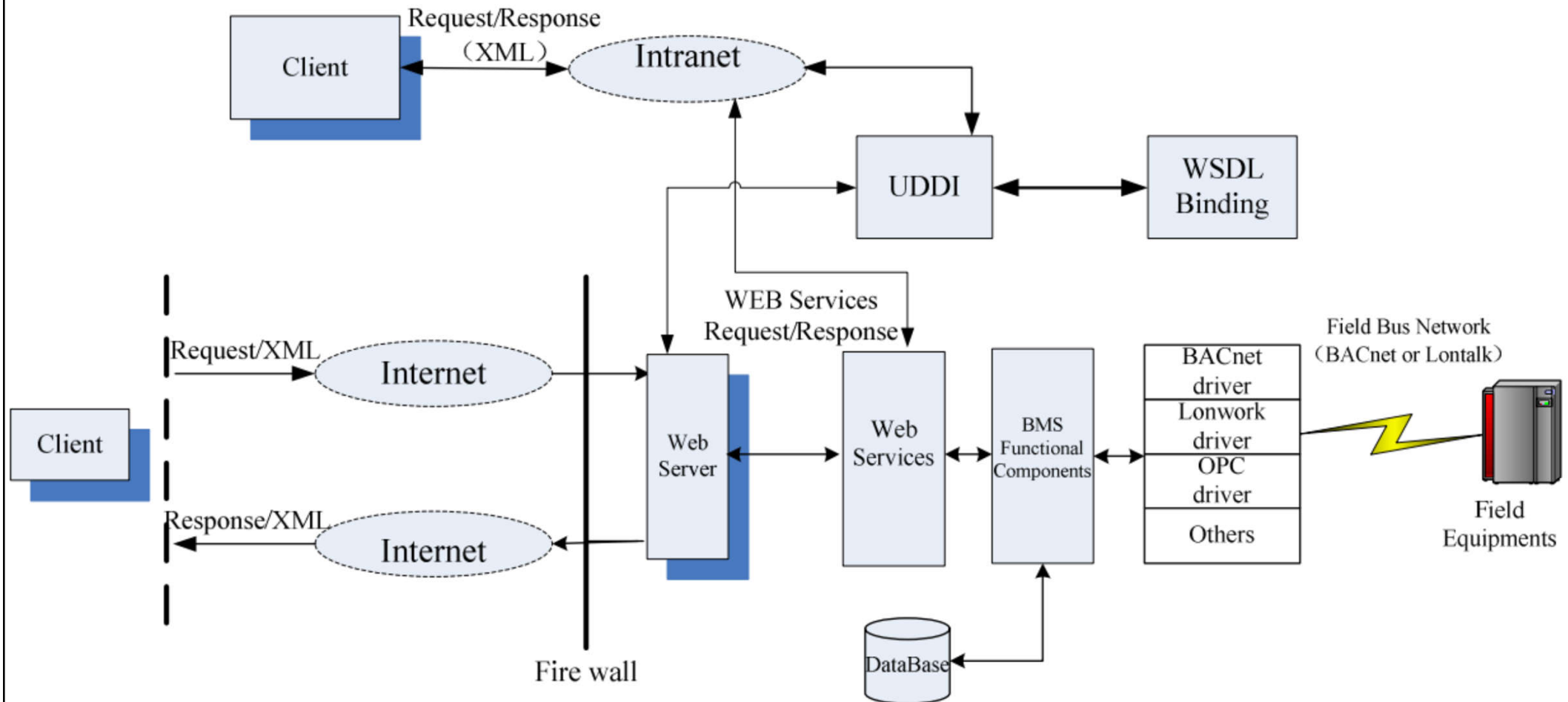
BAS architecture based on Web Services



UDDI = Universal Discovery Description and Integration
WSDL = Web Services Description Language
HTTP = HyperText Transfer Protocol

XML = Extensible Markup Language
SOAP = Simple Object Access Protocol

BAS internal structure sketch map based on Web Services



UDDI = Universal Discovery Description and Integration
 WSDL = Web Services Description Language

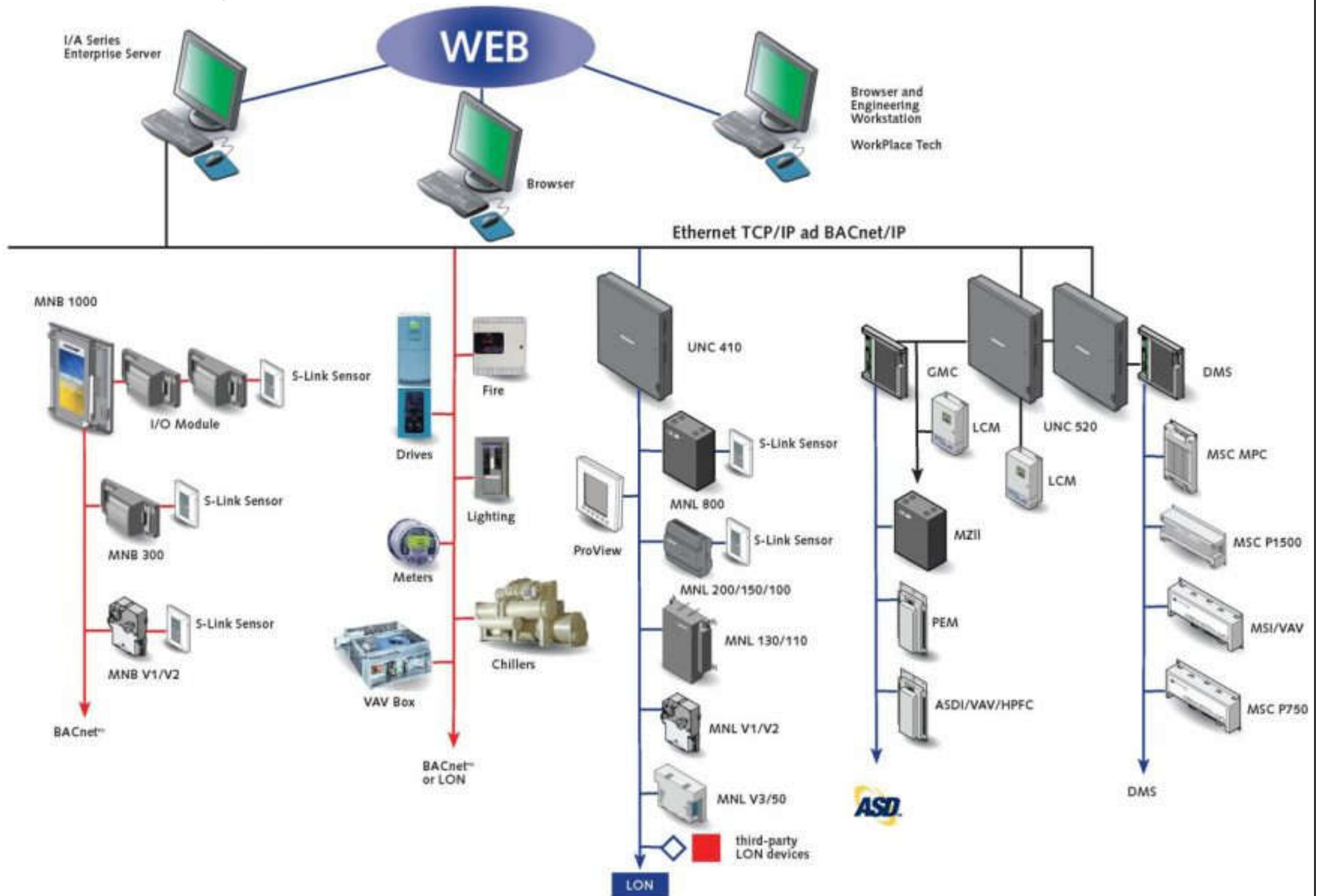
XML = Extensible Markup Language
 OPC = Open Platform Communications

Basic concepts

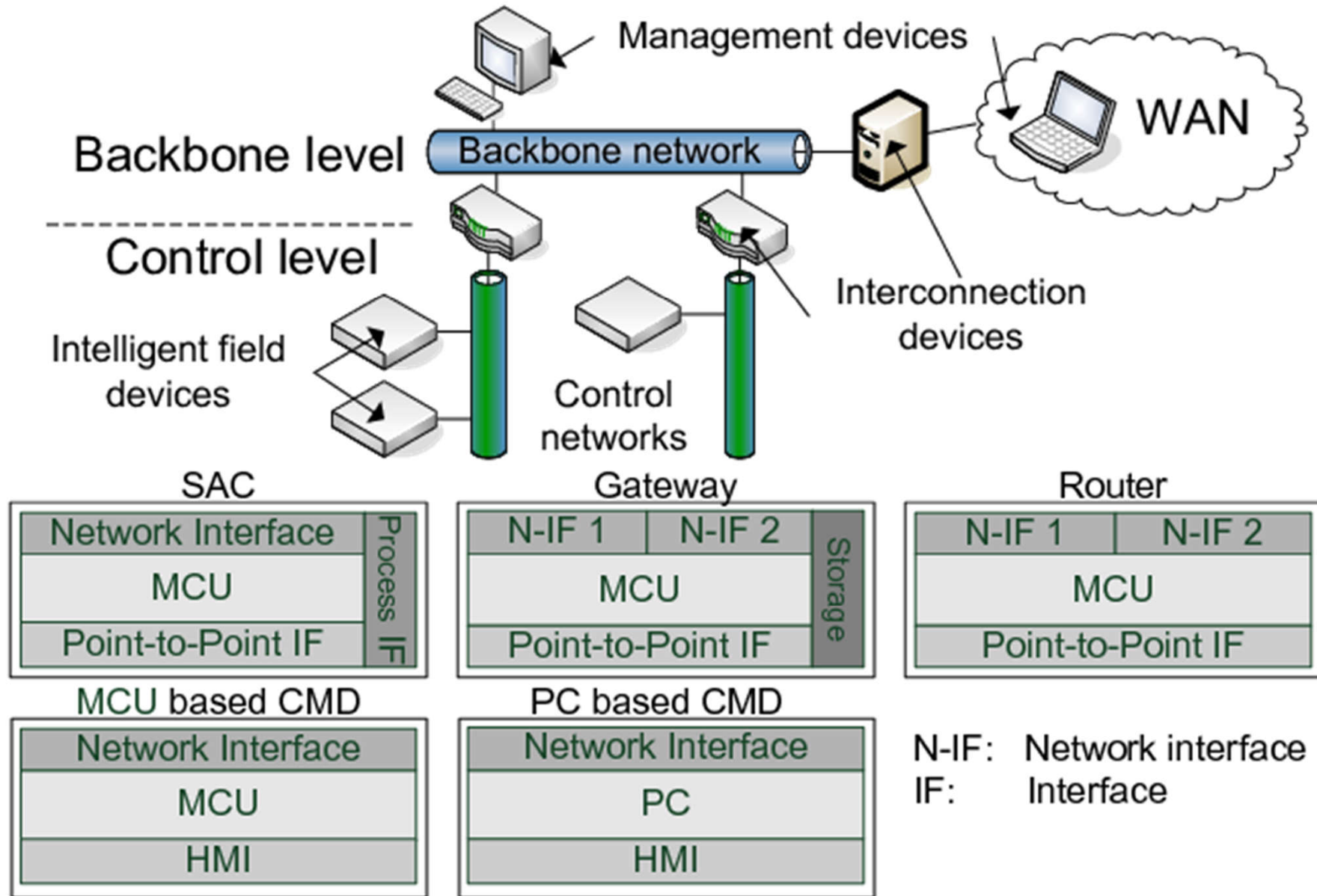


- Applications of Internet technologies in BAS
 - 1. Smart energy management
 - 2. Efficient automation & control of HVAC & other building systems & equipment
 - 3. Smart lighting control
 - 4. Predictive maintenance (to detect potential problems in building equipment & systems)
 - 5. Remote monitoring & control
 - Allow building managers to monitor & adjust settings from anywhere in the world

System architecture of an Internet/Web-based BAS



Internet-based building automation system (BAS) architecture



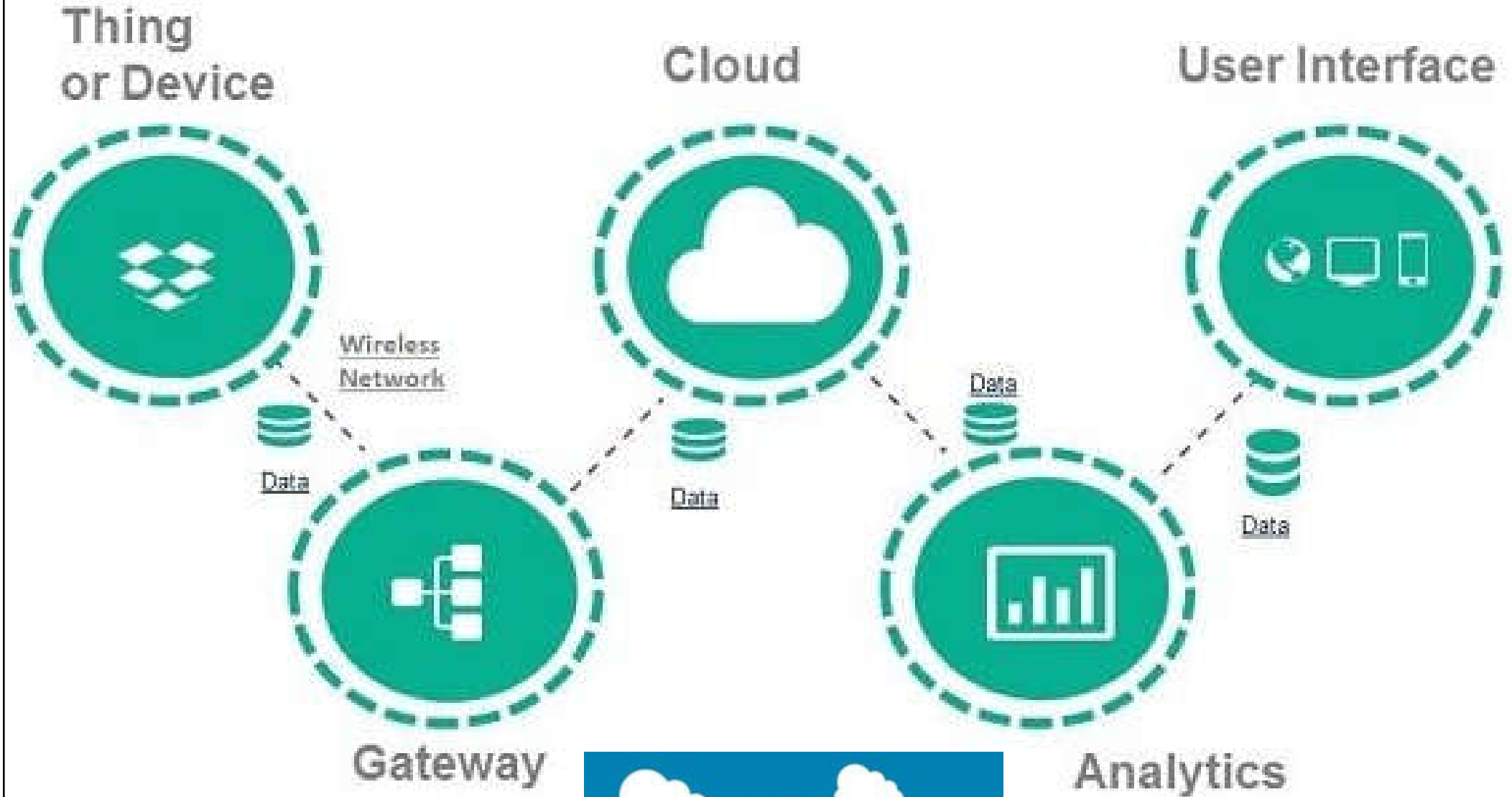
CMD = Configuration and management devices; ICD = Interconnection devices; IF = Interface; MCU = Microprocessor unit; SAC = Sensor, actuators and controllers; WAN = Wide area network

Basic concepts



- Key technologies
 - 1. Internet of Things (IoT) devices
 - Collect data on building conditions & equipment performance to monitor & regulate various systems
 - 2. Cloud storage & solutions
 - Store enormous amounts of data on cloud servers
 - 3. Data analytic for insights
 - Use machine learning (ML) algorithms that improve energy efficiency & lower operational costs over time
 - 4. Integration platform (for multiple technologies)

Major components of Internet of Things (IoT)



Basic concepts



- Intelligent IoT building features:
 - 1. Advanced environmental control
 - Respond to outdoor temperature, time of day, number of occupants & activity levels
 - 2. Efficient lighting design & operation
 - Respond to ambient light, time of day, room requirements (e.g. dimmed lights for presentations), occupancy levels, safety & security concerns
 - 3. Smart sanitation & water supply
 - Control water consumption, lower costs and improve the health & comfort levels



Basic concepts

- Intelligent IoT building features: (cont'd)
 - 4. Smart entry & intelligent security
 - Increase overall safety and improve your staff's ability to respond to threats & dynamic events
 - Access control, security cameras, employee identification information
 - 5. Self-diagnosing systems
 - Identify problems & adjust systems to reduce the potential impact
 - 6. Disaster avoidance
 - Mitigate catastrophic failures or disasters

Integration of multiple systems for building automation system

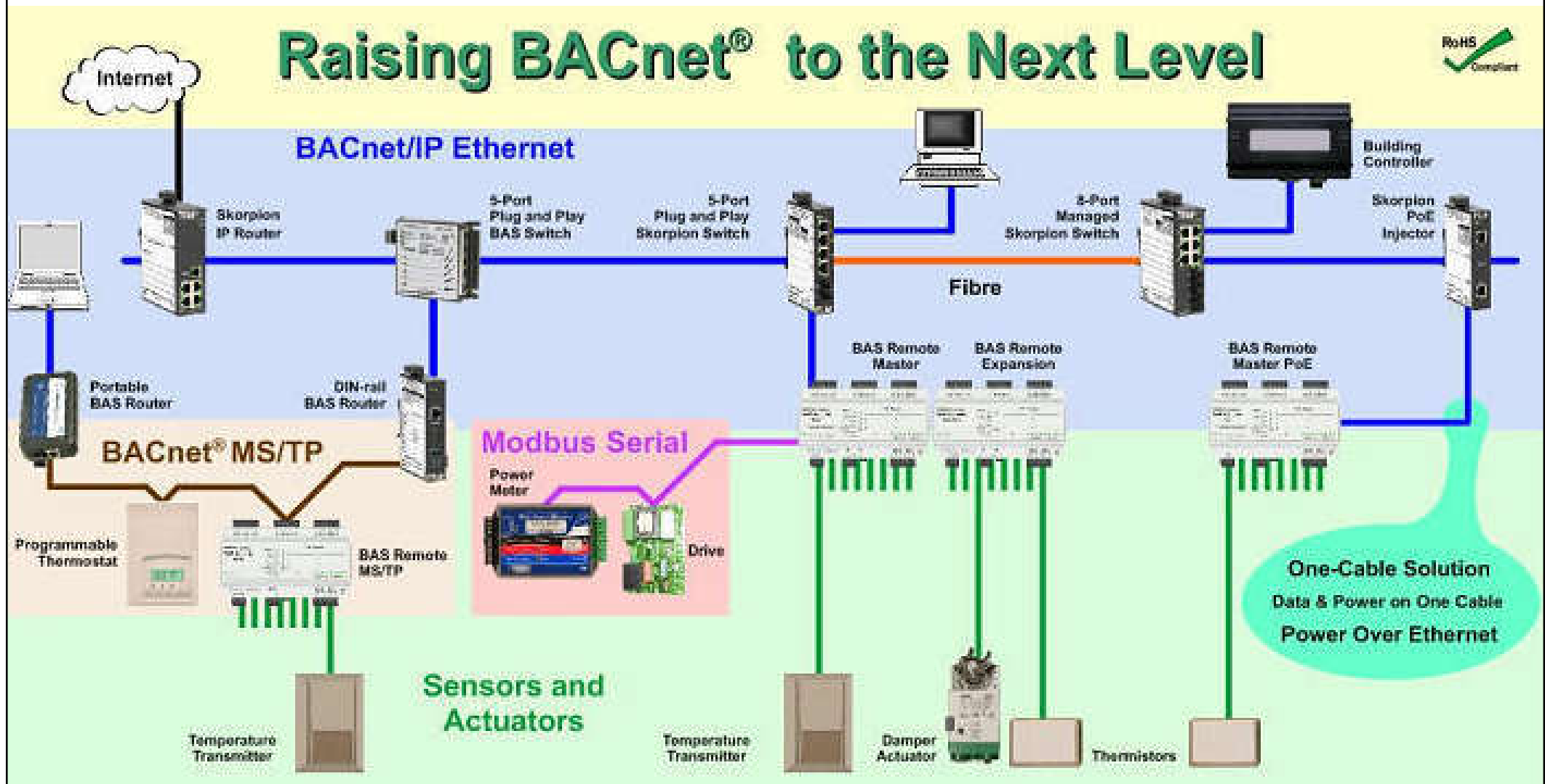




IP-based networks

- Web services & Internet Protocol (IP)
 - A revolution in the networking & computing industries - The Internet & its associated protocols became the dominate driving force for technology in the 90s
 - Computers of all different types, with different operating systems, from different manufacturers, came together in cyberspace under a unified set of protocols

Typical BAS system using an IP infrastructure



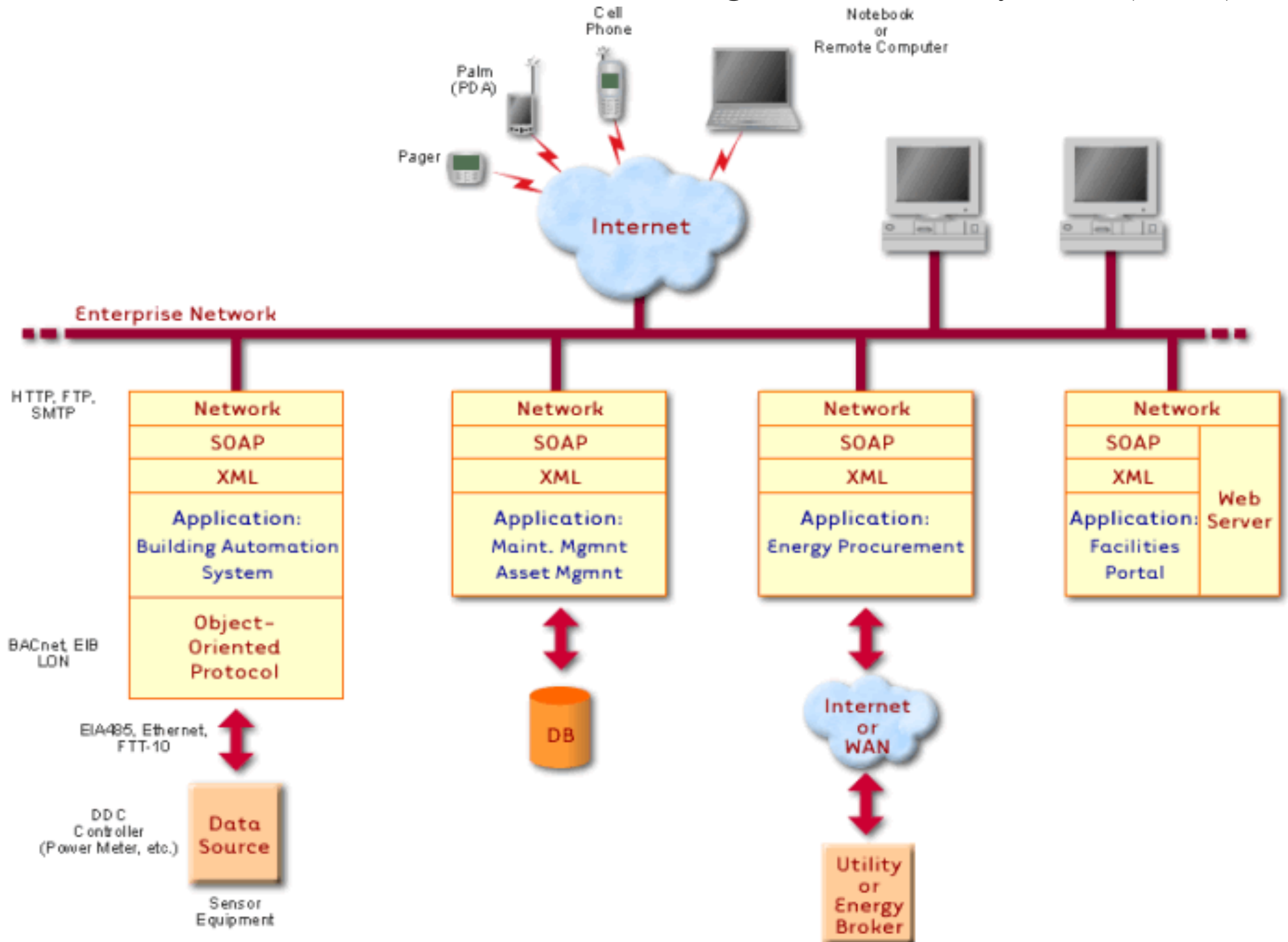
Video: IP Networking in Smart Buildings (2:27) <https://youtu.be/rny-n6vrb7Y>



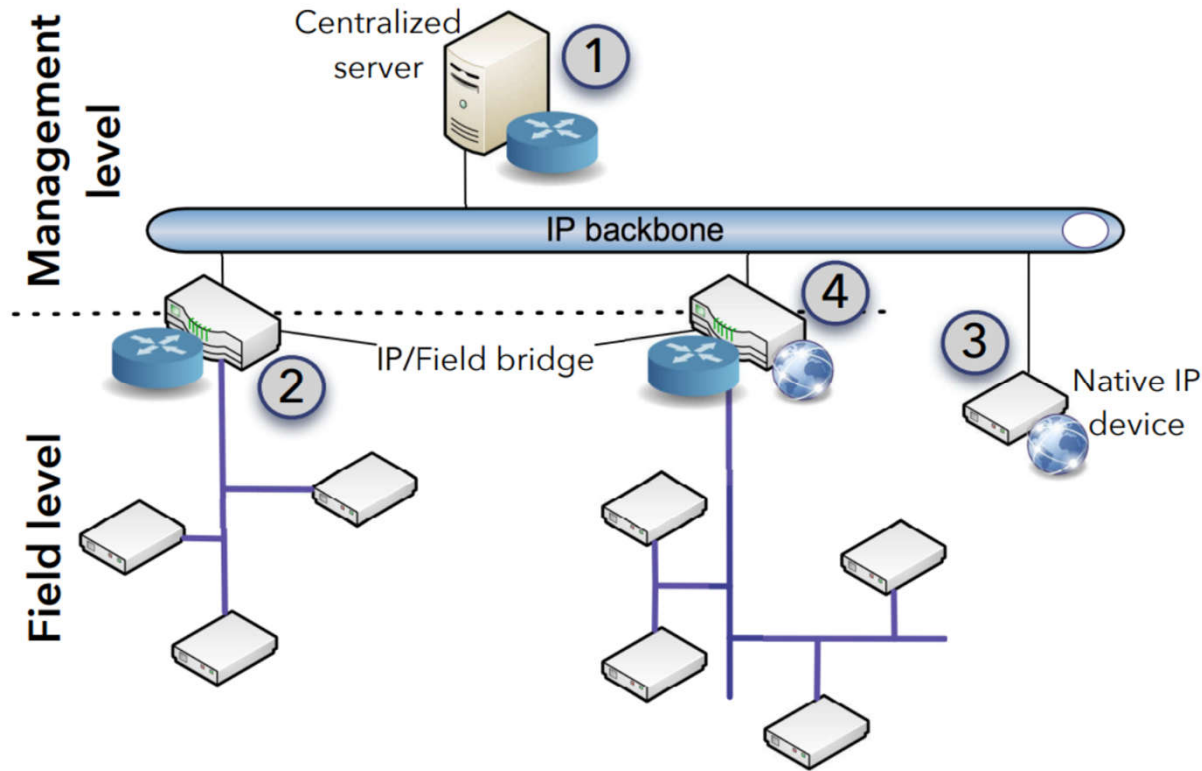
IP-based networks

- Advantages of using Internet Protocols (IPs) BAS:
 - They are well defined & widely accepted
 - They are free (no single company controls them)
 - They are continually improved & benefit from R&D from thousands of companies across hundreds of industries
 - They allow BAS to cross industry boundaries & interface with a wide variety of other systems
 - They allow separate systems and groups of components to share the same set of wires (this reduces the overall cost of installing & maintaining several systems)

Web services architecture for building automation system (BAS)

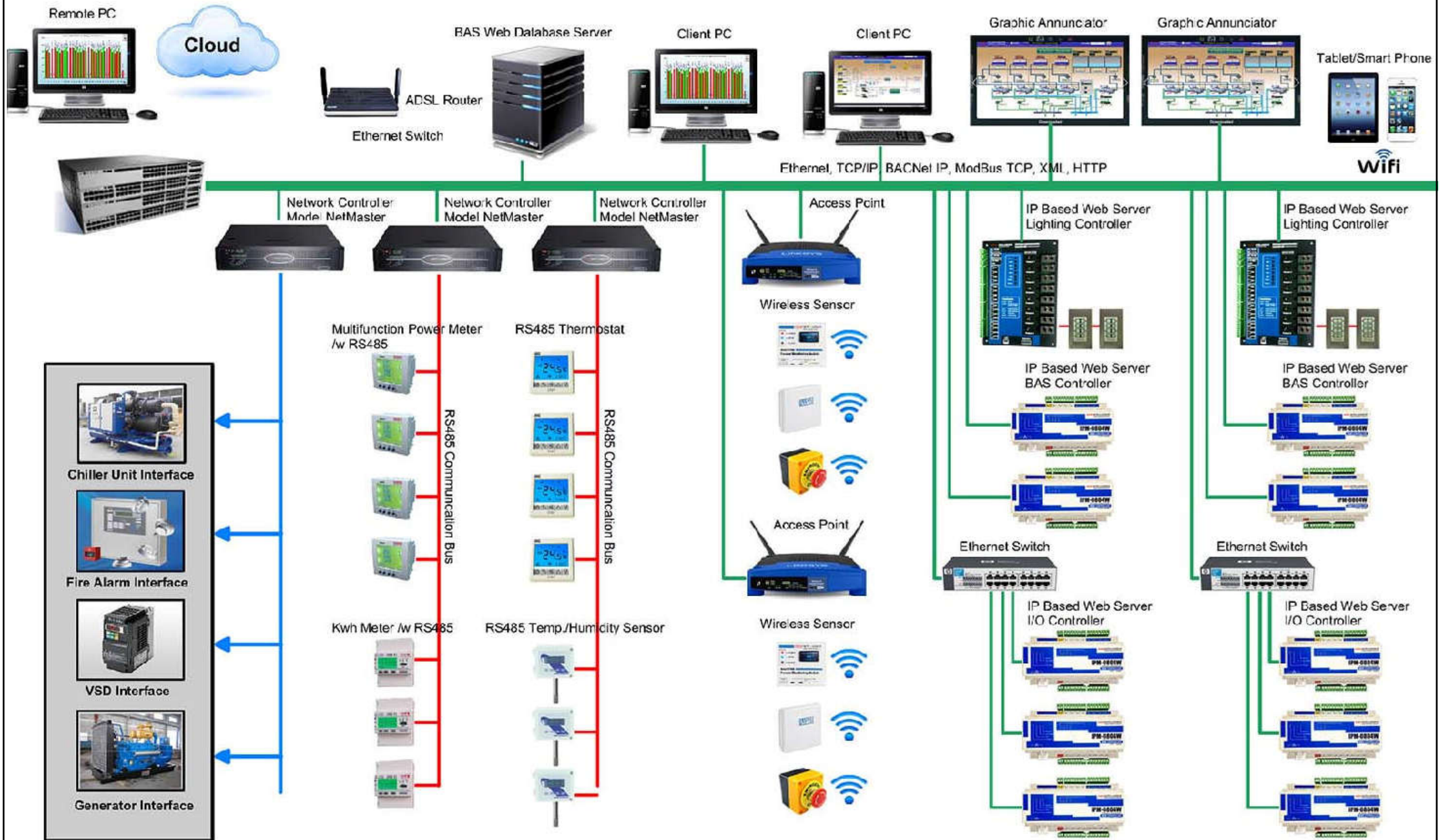


Four different Web integration styles of building automation systems



1. **On a centralized server:** this approach is currently the most used one where a server at the IP backbone handles all the interaction with the BAS. It allows an integration into enterprise systems.
2. **On a bridge:** by encapsulating field telegrams into IP packets one can interact with the BAS. Although being a more decentralized approach, the same problem regarding the application level remains open.
3. **On field devices:** IP enabled devices offering Web services for intercommunication with other participants of the network.
4. **Multi-stack bridges:** allow a more decentralized approach. By implementing the field stack and the IoT stack, mappings between Web services and endpoints are possible. By proceeding this way remote devices acting as clients are not aware that the final device resides on another type of network even having no IP connectivity.

Example of a web-based building automation system with IP-based network controllers, wireless sensors & communication bus



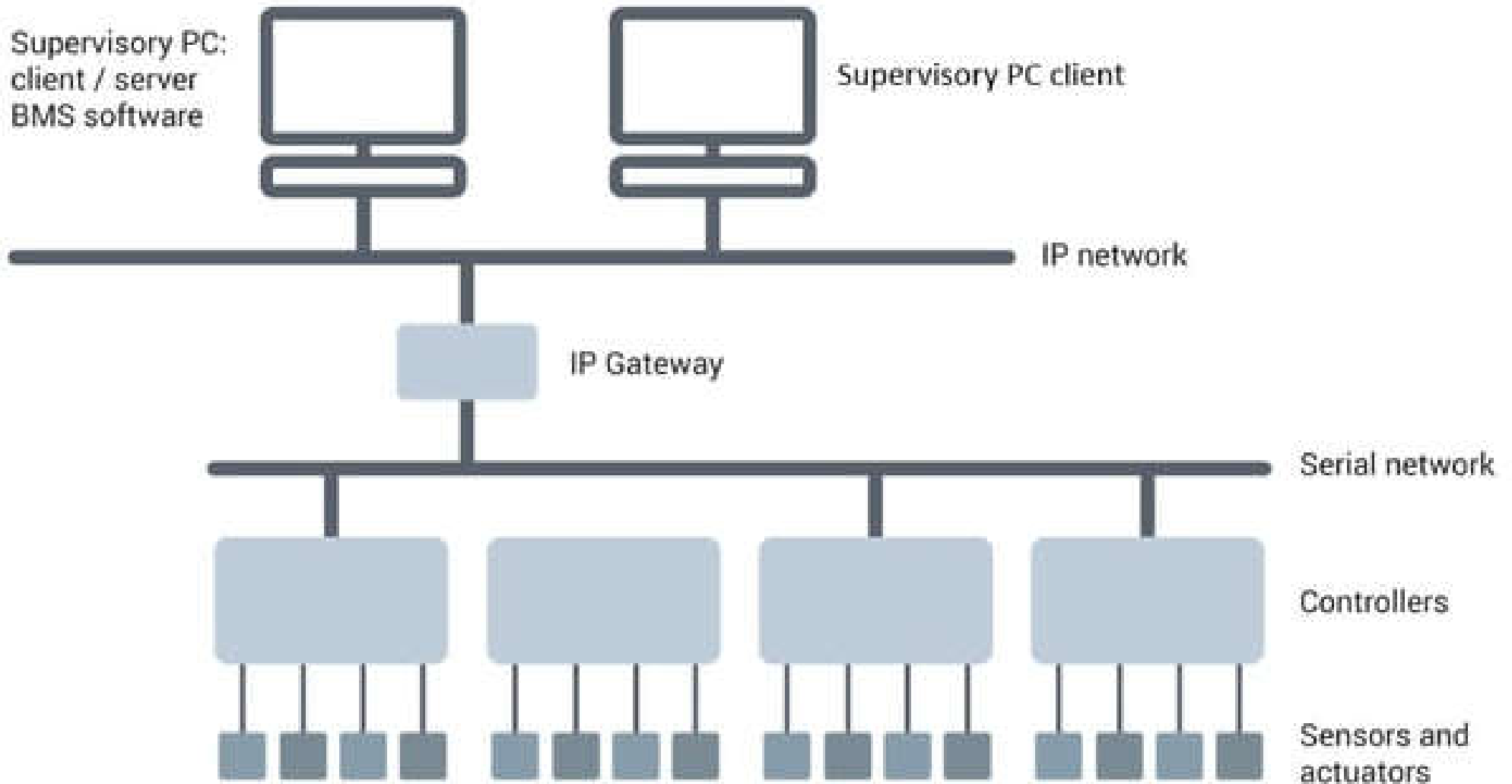


IP-based networks

- Benefits of web-based building control:
 - Ability to access information & control buildings from anywhere
 - Ability to access information with a variety of devices, from desktop PCs, laptop computers & tablets, to web-enabled cell phones
 - Elimination of multiple databases, minimizing management needs
 - Offer end-to-end operating freedom & no need for add-on software

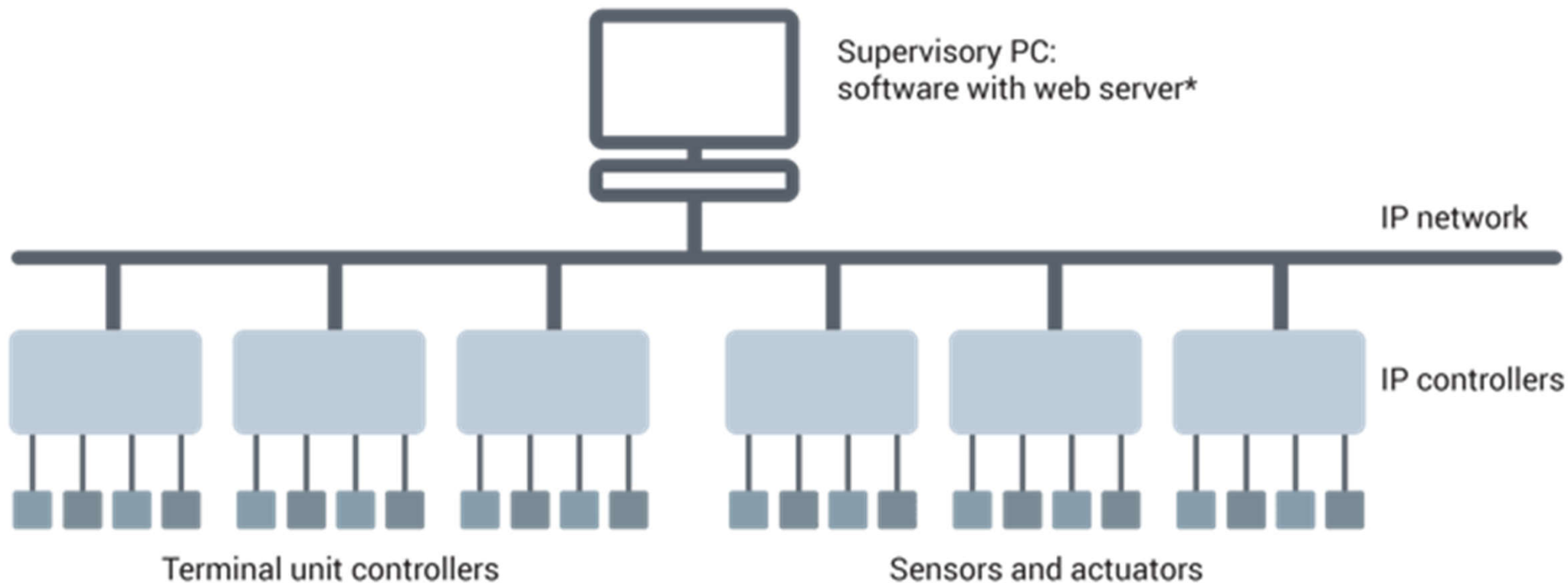
Distributed BAS serial controllers bridged to IP with client/server for multiple supervisory graphics

systems from the mid 1990s

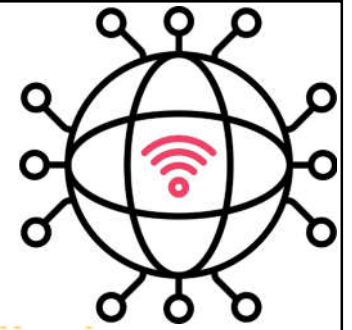


Distributed BAS with flat IP network for all controllers with web-served supervisory graphics

some systems since ~2015



*Supervisory BMS software with web server is now typically run on a fan-less embedded platform or on a server in the IT suite rather than on a desktop PC

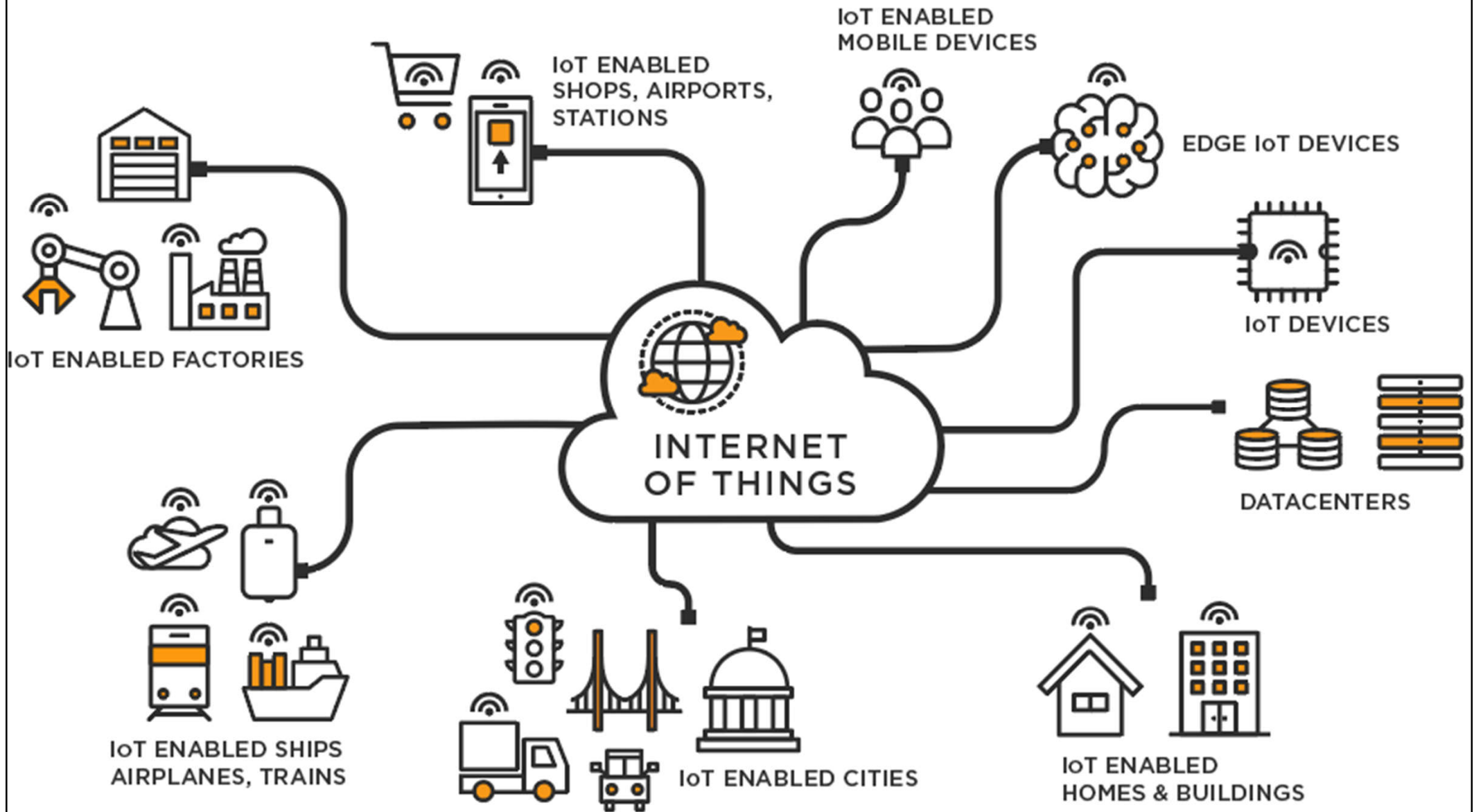


Internet of Things (IoT)

- **Internet of Things (IoT)** involves connecting everyday objects & devices to the Internet, enabling them to gather & exchange data
 - From machinery & tools to sensors & wearable devices, they can communicate & collaborate seamlessly to create better insights
 - Leverage IoT technology to establish a sophisticated network of sensors, controls & systems that work together to create an intelligent & responsive environment

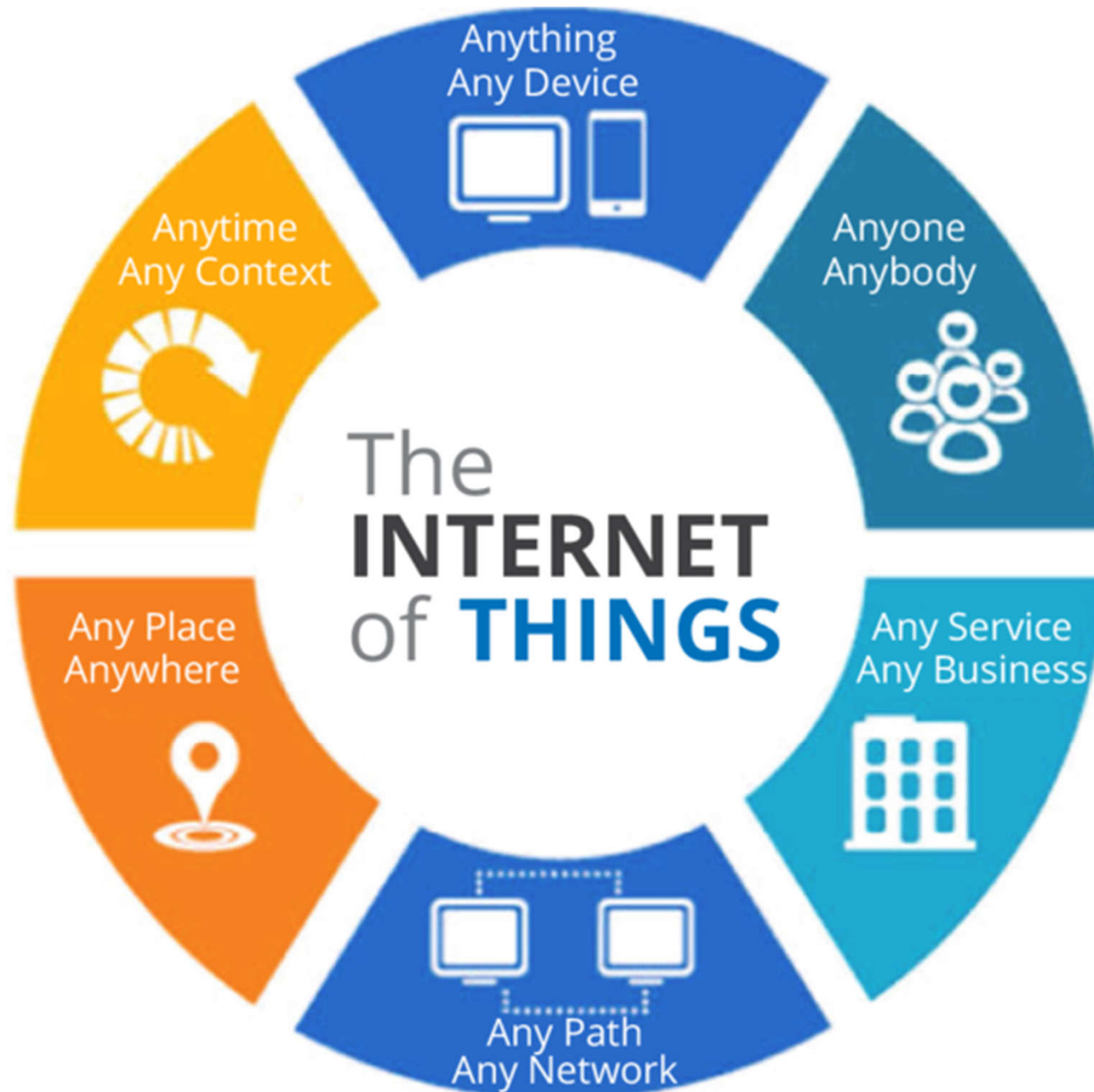
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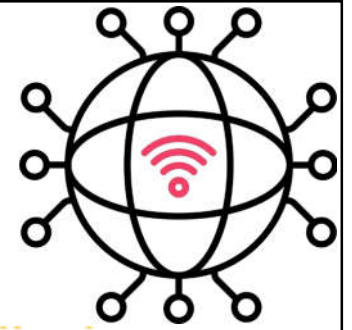
What is Internet of Things (IoT)?



Video: Internet of Things (IoT) | What is IoT | How it Works | IoT Explained | Edureka (3:21) <https://youtu.be/LlhmzVL5bm8>

Internet of Things takes all the things in the information from the world
& connects them through the Internet

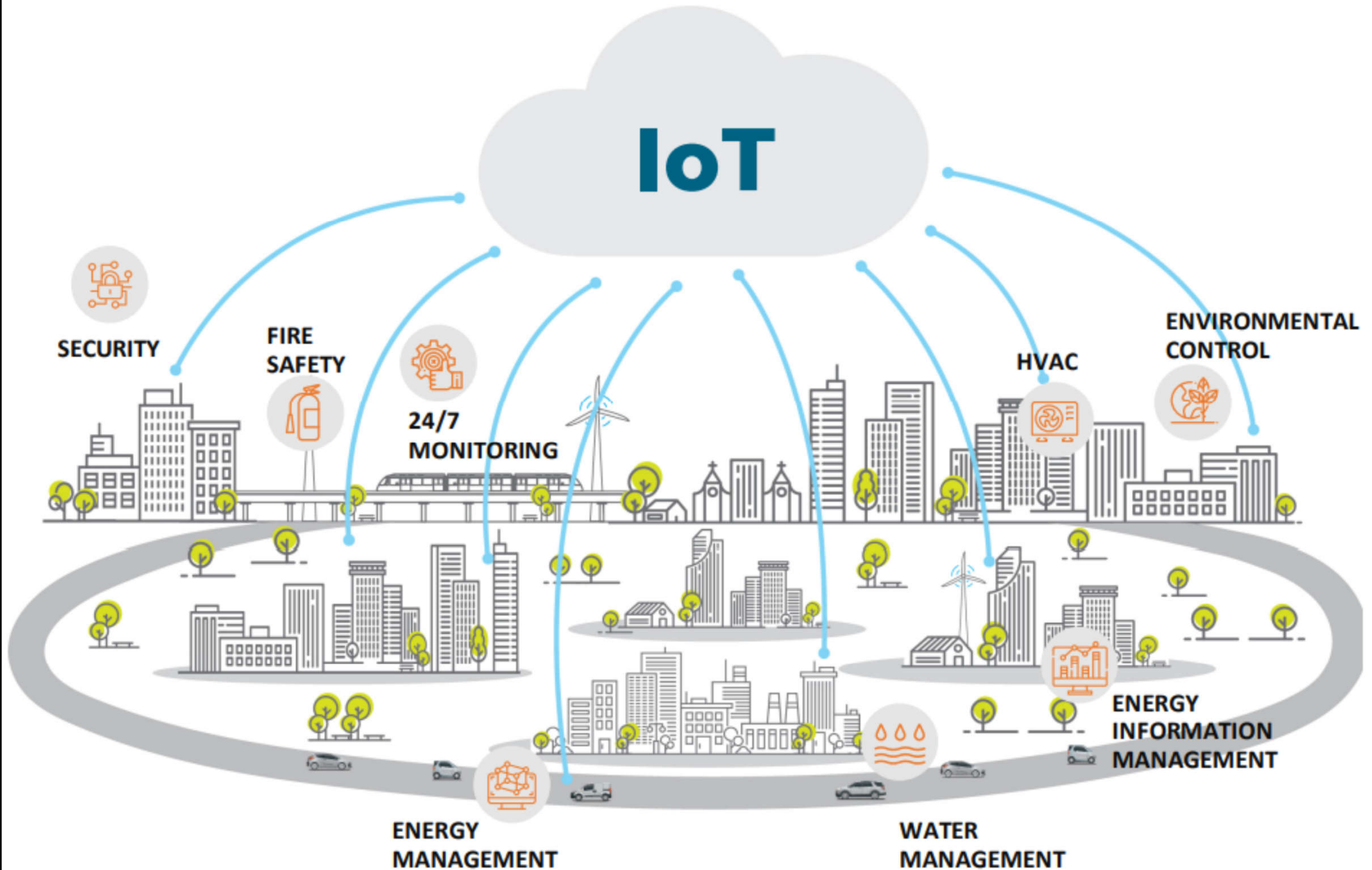




Internet of Things (IoT)

- IoT protocols:
 - 1. MQTT (Message Queue Telemetry Transport)
 - 2. DDS (Data Distribution Service)
 - 3. AMQP (Advanced Message Queuing Protocol)
 - 4. Constrained Application Protocol (CoAP)
- IoT communication technologies:
 - Bluetooth, Zigbee, Wi-Fi, Cellular (3G, 4G, 5G), LoRaWAN (Long Range Wide Area Network)

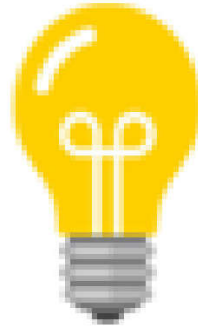
Internet of Things (IoT) as a 'backbone' to smart green buildings



Different IoT-based systems in smart buildings



Motion Sensors



Lighting



Smart camera



Smart TV



Smart Lock System



Thermostat



Smart Building

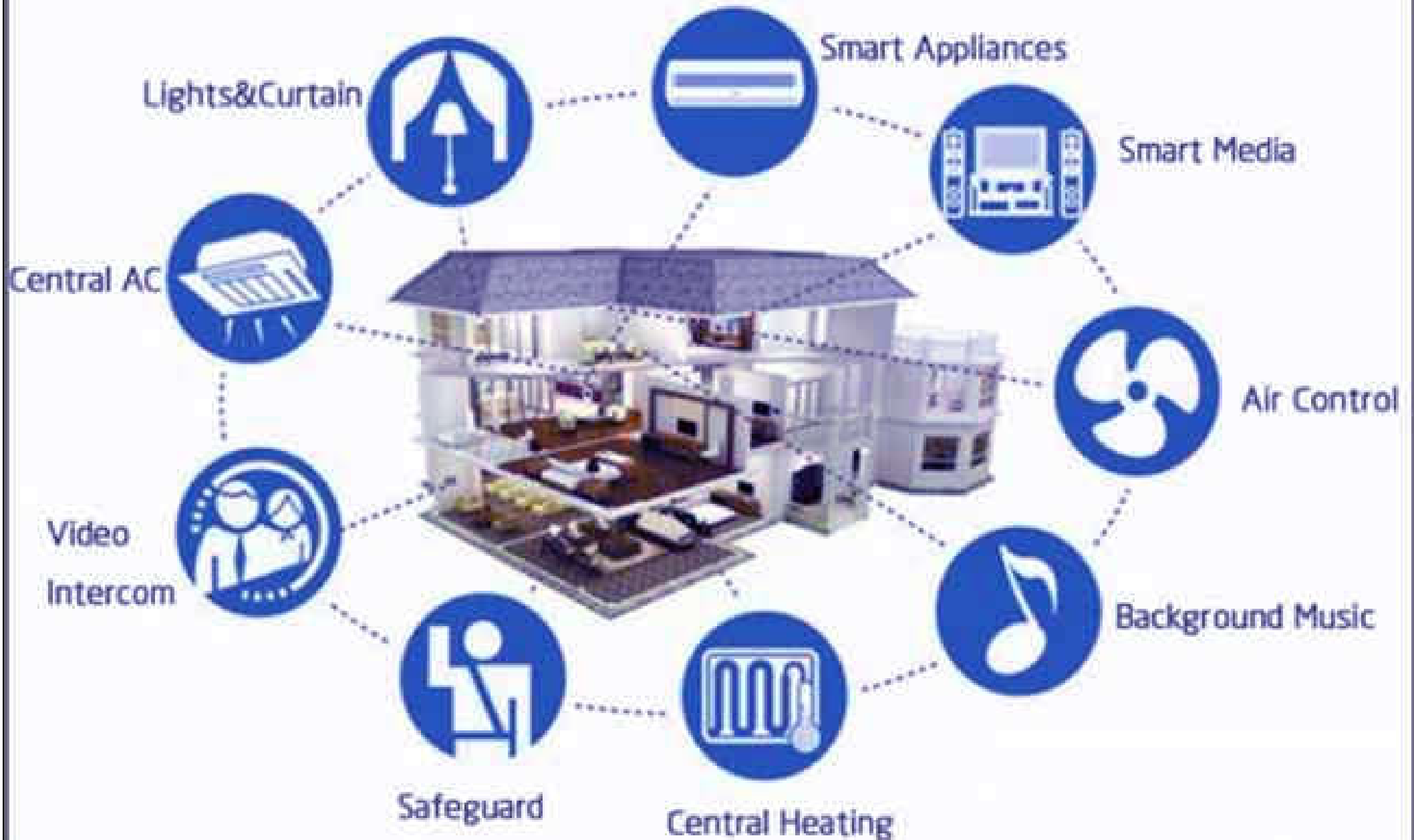


Smart Energy Management



Smart Door Bell

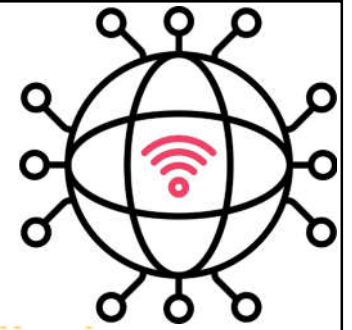
Internet of Things (IoT) applications in buildings & houses



Possible functions provided by Internet of Things (IoT) in buildings

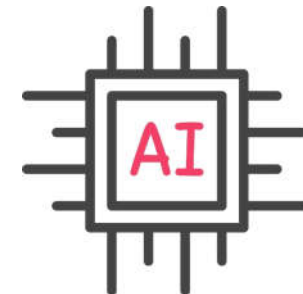
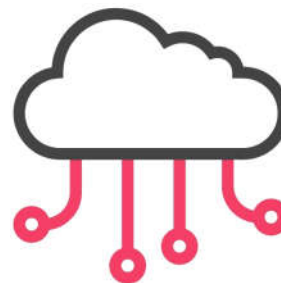
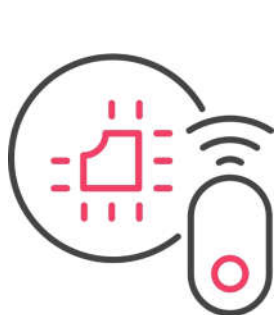


(Source: <https://data-flair.training/blogs/internet-of-things-applications-in-building/>)

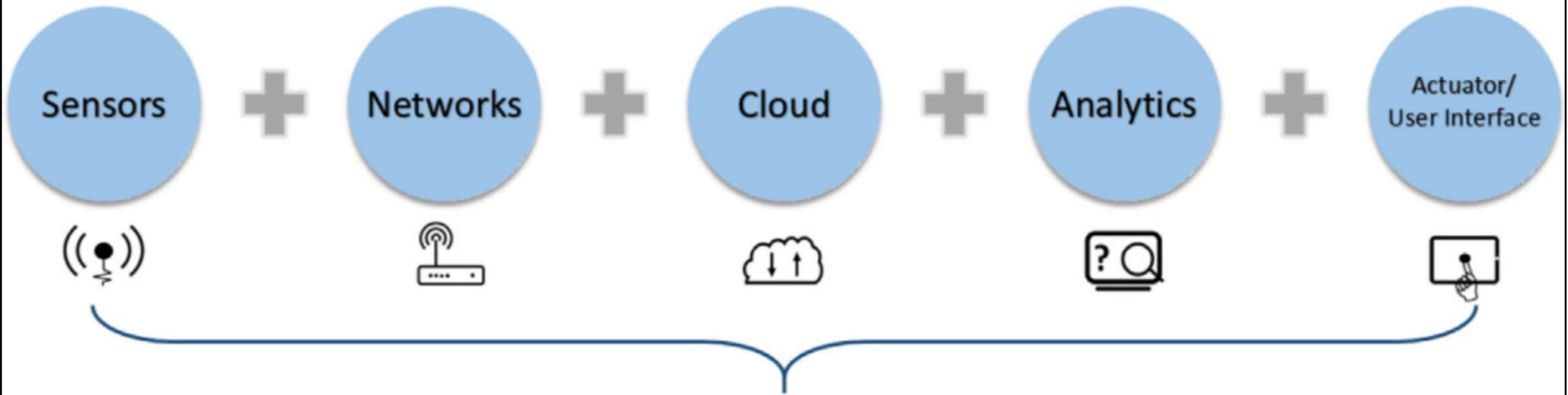


Internet of Things (IoT)

- Key components in IoT-powered building automation system:
 - 1. IoT sensors
 - 2. Smart devices/actuators
 - 3. Cloud computing
 - 4. Artificial intelligence & data analytics



Components of an IoT system



IoT Ecosystem



1

Sensors

Collecting data



2

Connectivity

Sending data to cloud



3

Data Processing

Making data useful

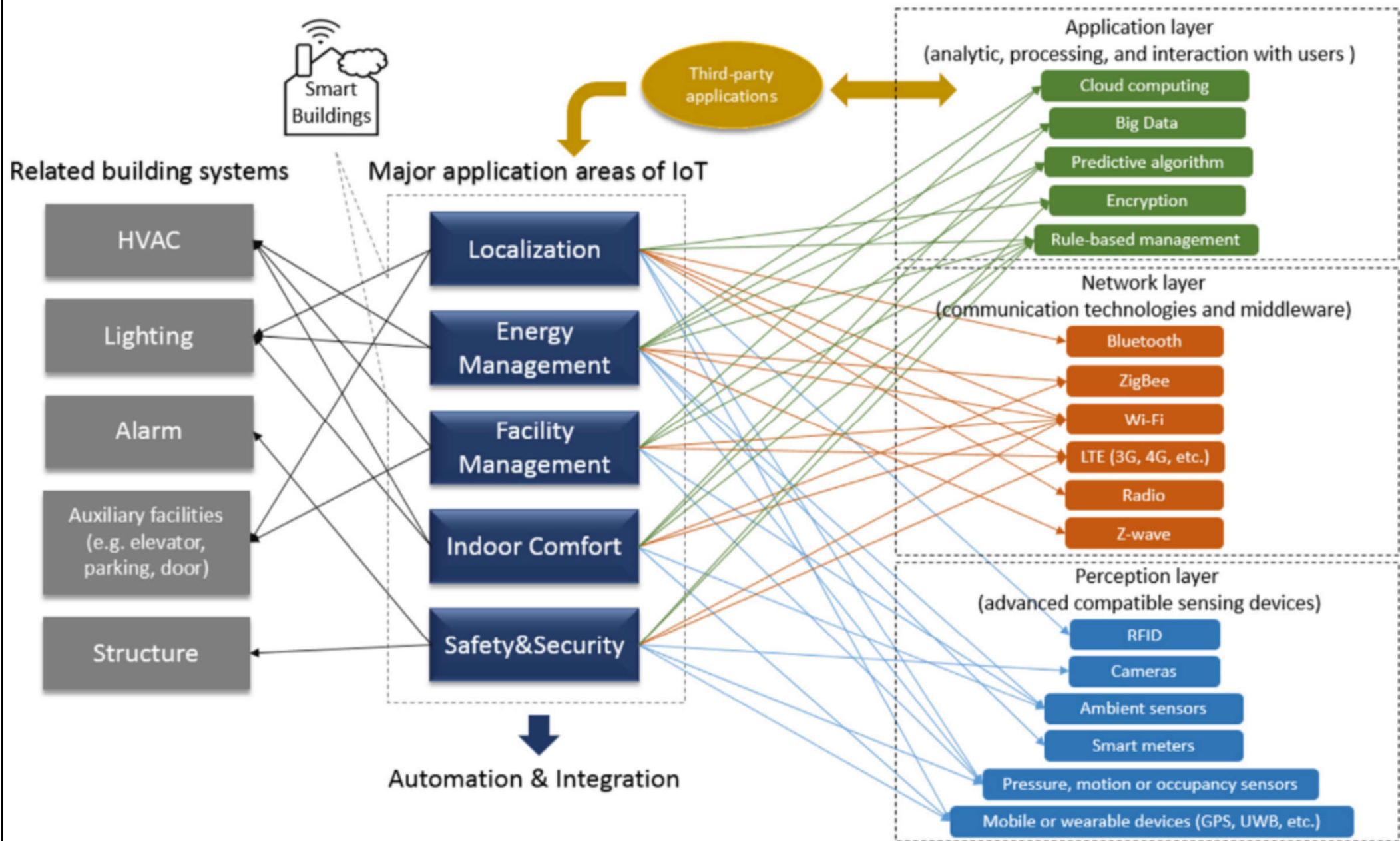


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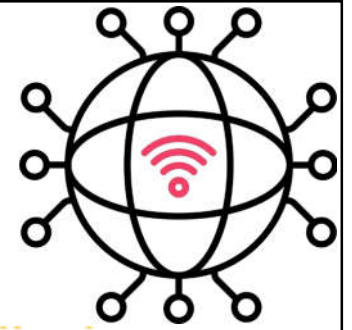
User Interface

Delivering information to user

Application of IoT on smart buildings (goals, technologies, and related building systems)

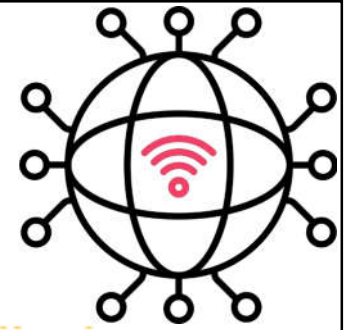


(Source: Jia M., Komeily A., Wang Y. & Srinivasan R. S., 2019. Adopting Internet of Things for the development of smart buildings: A review of enabling technologies and applications, *Automation in Construction*, 101: 111-126. <https://doi.org/10.1016/j.autcon.2019.01.023>)



Internet of Things (IoT)

- How IoT enables smart building automation
 - Security & emergency: Smart IoT access control with ID or face recognition; IoT sensors on fire, chemical leakage, or flood
 - Advanced maintenance: Setting IoT alerts for state tracking & conducting predictive maintenance
 - Energy management: Optimise energy use with customized settings for greater energy efficiency
 - Waste management: Optimise resource use to reduce utility bills & carbon footprint

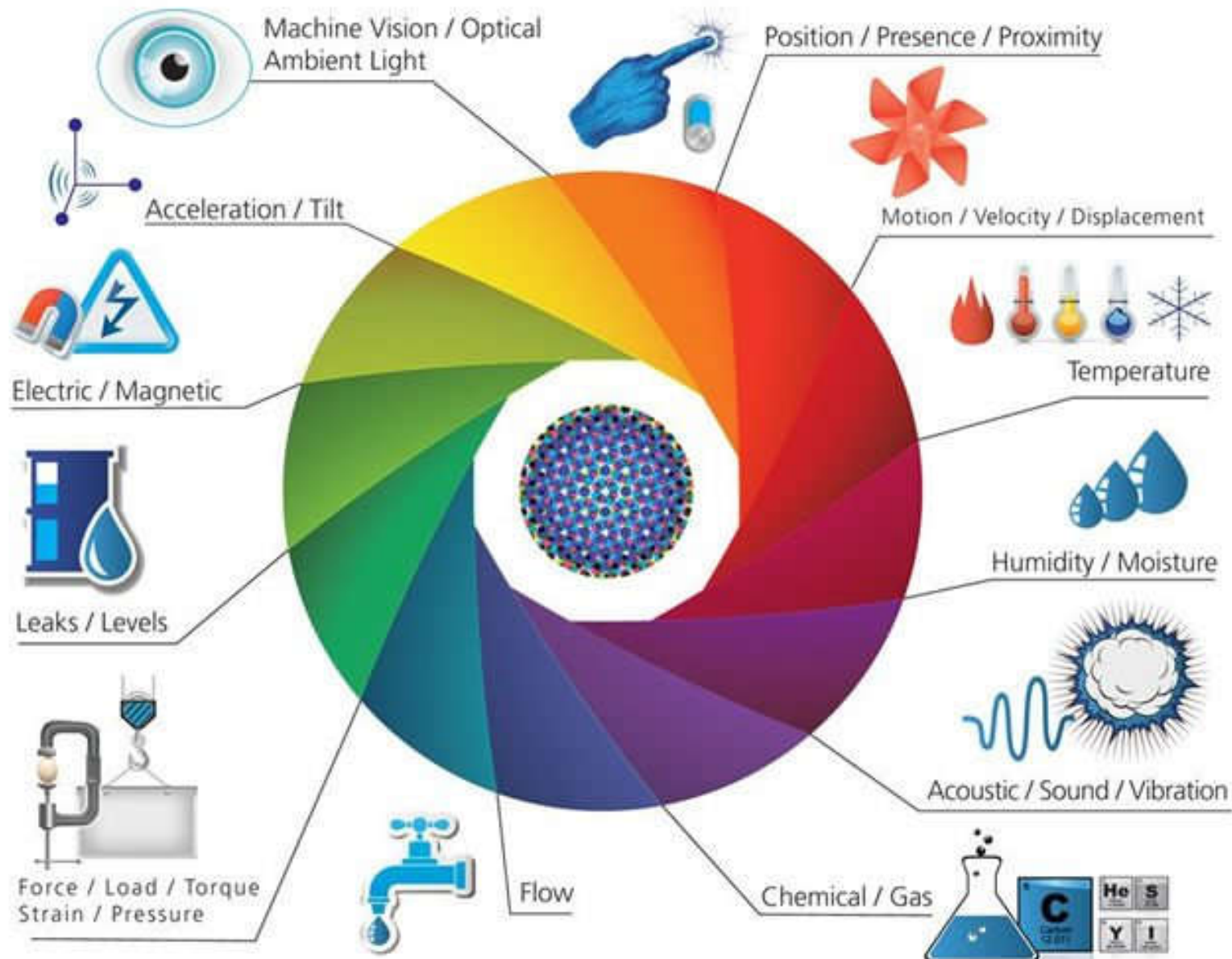


Internet of Things (IoT)

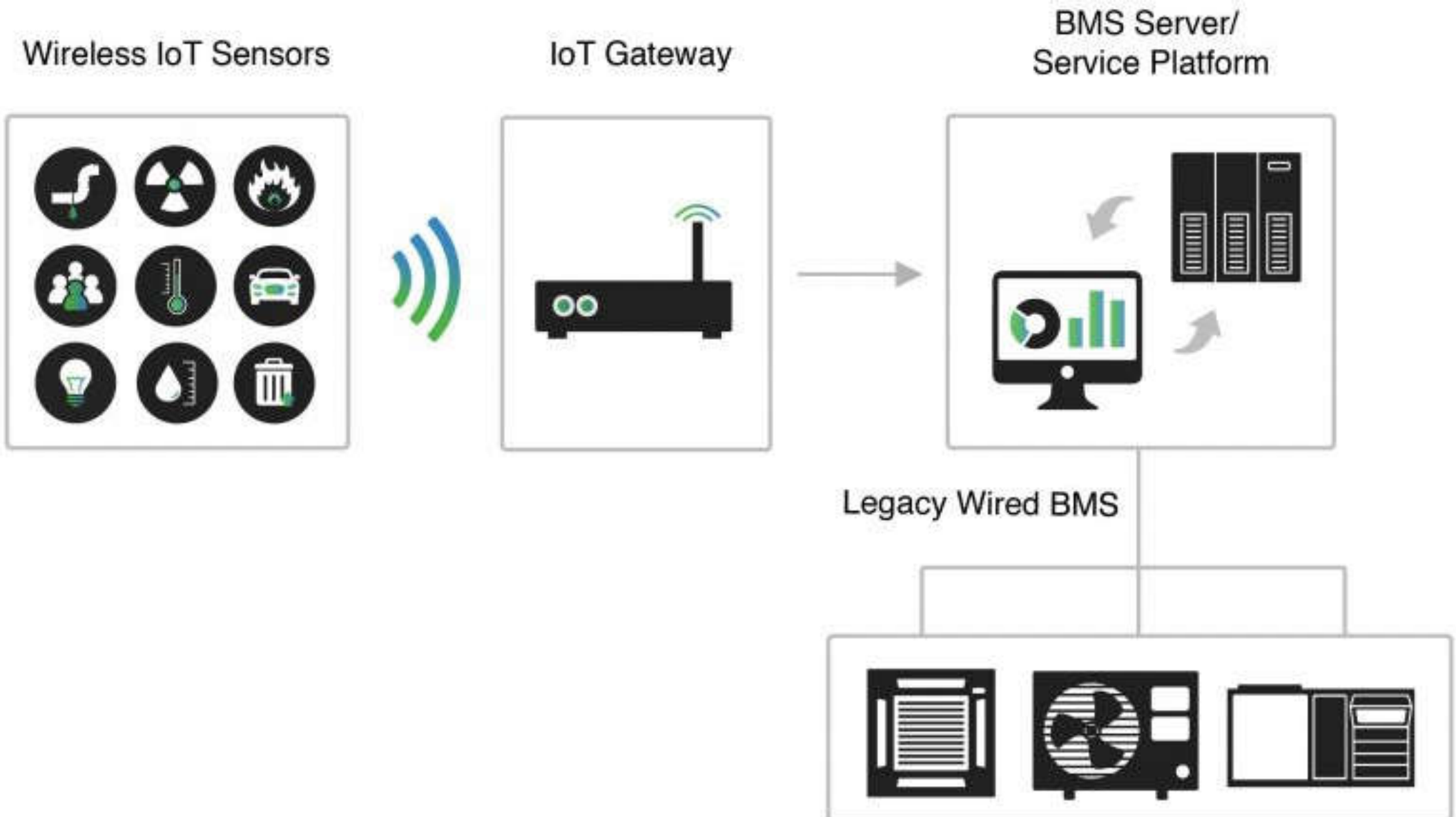
- Internet of Things (IoT) networks building technologies
 - Sensing technology
 - Wireless communication technology
 - Cloud computing technology
 - Radio-frequency identification (RFID) intelligent identification technology
 - Internet Protocol version 6 (IPv6) technology

1 SENSORS & ACTUATORS

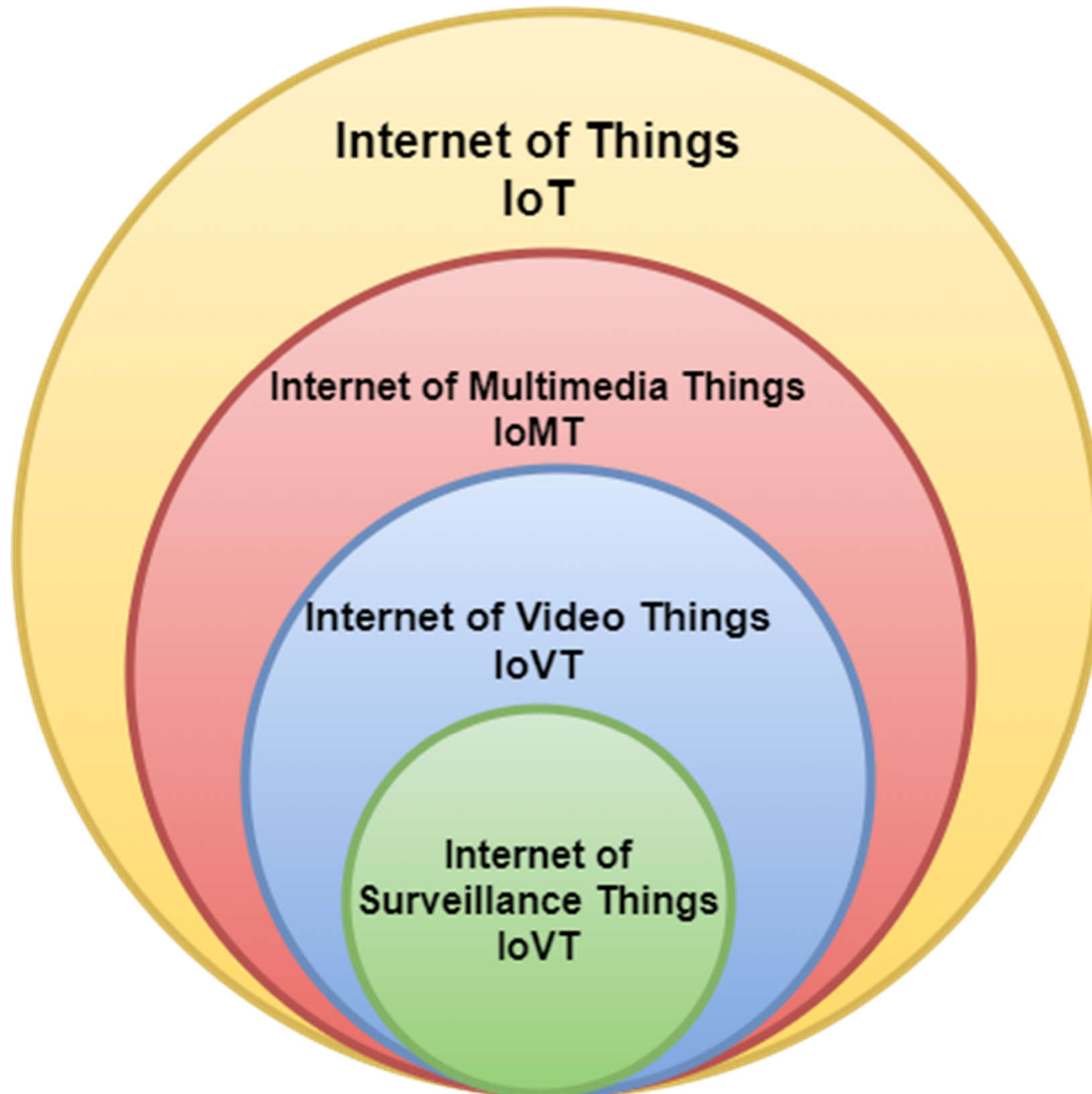
We are giving our world a digital nervous system. Location data using GPS sensors. Eyes and ears using cameras and microphones, along with sensory organs that can measure everything from temperature to pressure changes.



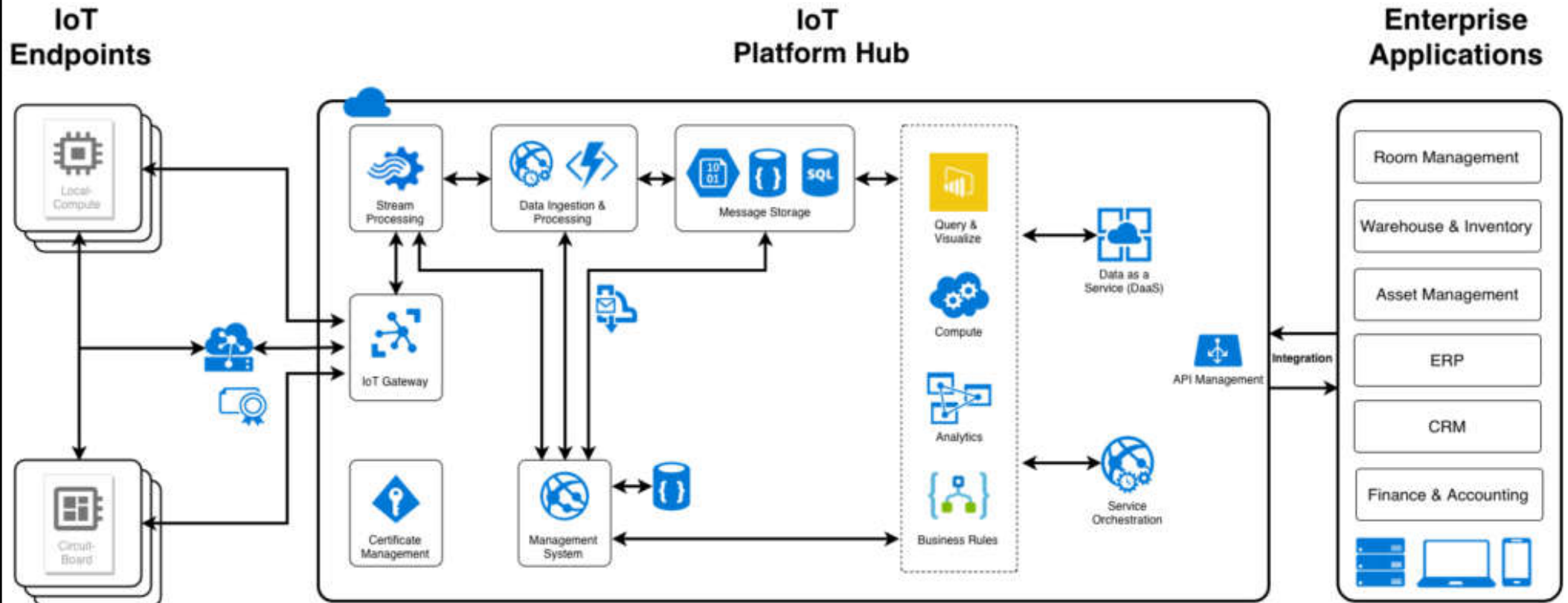
Wireless IoT sensors to support BAS/BMS functions



Internet of Video Things (IoVT): Future of video surveillance systems

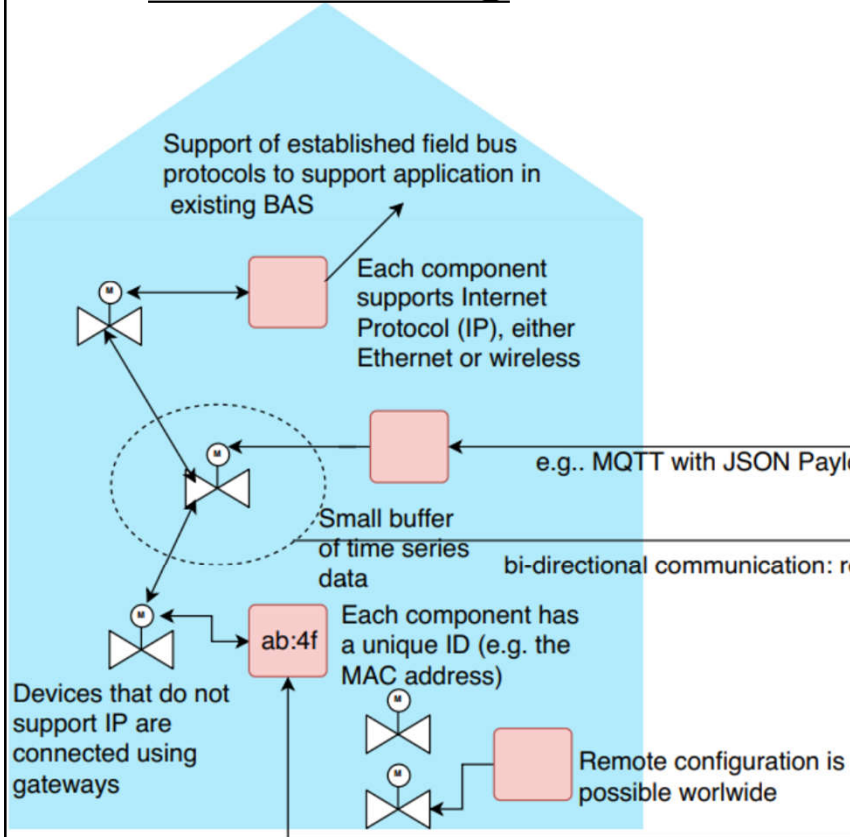


IoT platform hub to store, process & analyze the data before streamlining insights into enterprise management applications

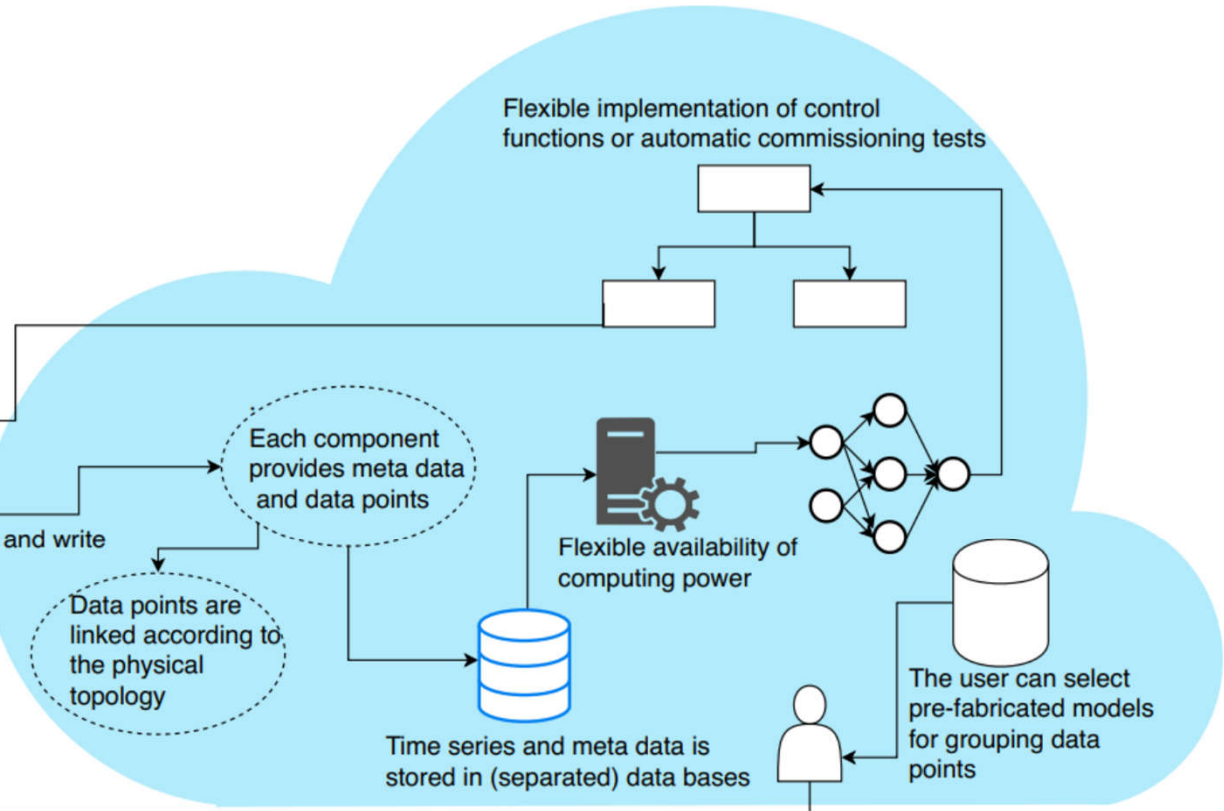


The proposed architecture for IoT BAS

The building



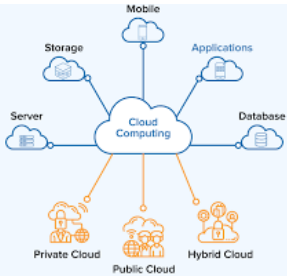
The cloud



Cloud-based services



- Cloud computing 雲端運算
 - The delivery of computing services -- including servers, storage, databases, networking, software, analytics & intelligence -- over the Internet (“the cloud”) to offer faster innovation, flexible resources & economies of scale
 - Can lower operating costs, run the infrastructure more efficiently & scale as the business needs change
 - 3 types: public cloud, private cloud, hybrid cloud



Cloud-based BAS



- Four types of cloud services:
 - 1. Infrastructure as a service (IaaS)
 - Rent IT infrastructure -- servers & virtual machines (VMs), storage, networks, operating systems) -- from a cloud provider on a pay-as-you-go basis
 - 2. Platform as a service (PaaS)
 - Supply an on-demand environment for developing, testing, delivering & managing software applications
 - Make it easier for developers to quickly create web or mobile apps

Cloud-based BAS



- Four types of cloud services: (cont'd)
 - 3. Software as a service (SaaS)
 - Deliver software applications over the internet, on demand & typically on a subscription basis
 - 4. Serverless computing
 - Focus on building app functionality without spending time continually managing the servers & infrastructure
 - The cloud provider handles the setup, capacity planning & server management
 - Highly scalable & event-driven, only using resources when a specific function or trigger occurs

Cloud-based, remote building automation systems (BAS) for commercial buildings

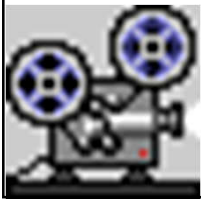


(Source: <https://www.esmagazine.com/articles/100953-building-automation-systems-to-the-rescue-creating-a-remote-world>)



Cloud-based BAS

- Using a cloud-based system, people can monitor & control their buildings from a PC or smart device from anywhere in the world
- A cloud-based BAS also provides high-level analytical reporting that is fully automated
- It can model environmental data several days into the future to automatically & continuously update settings



Video: Cloud Computing Services Explained | Cloud Computing Services - IaaS, PaaS & SaaS | Simplilearn (19:20) <https://youtu.be/PpX7TuR6DCY?si=-Ap6hLR3197gK-Jv>

Cloud-based BAS



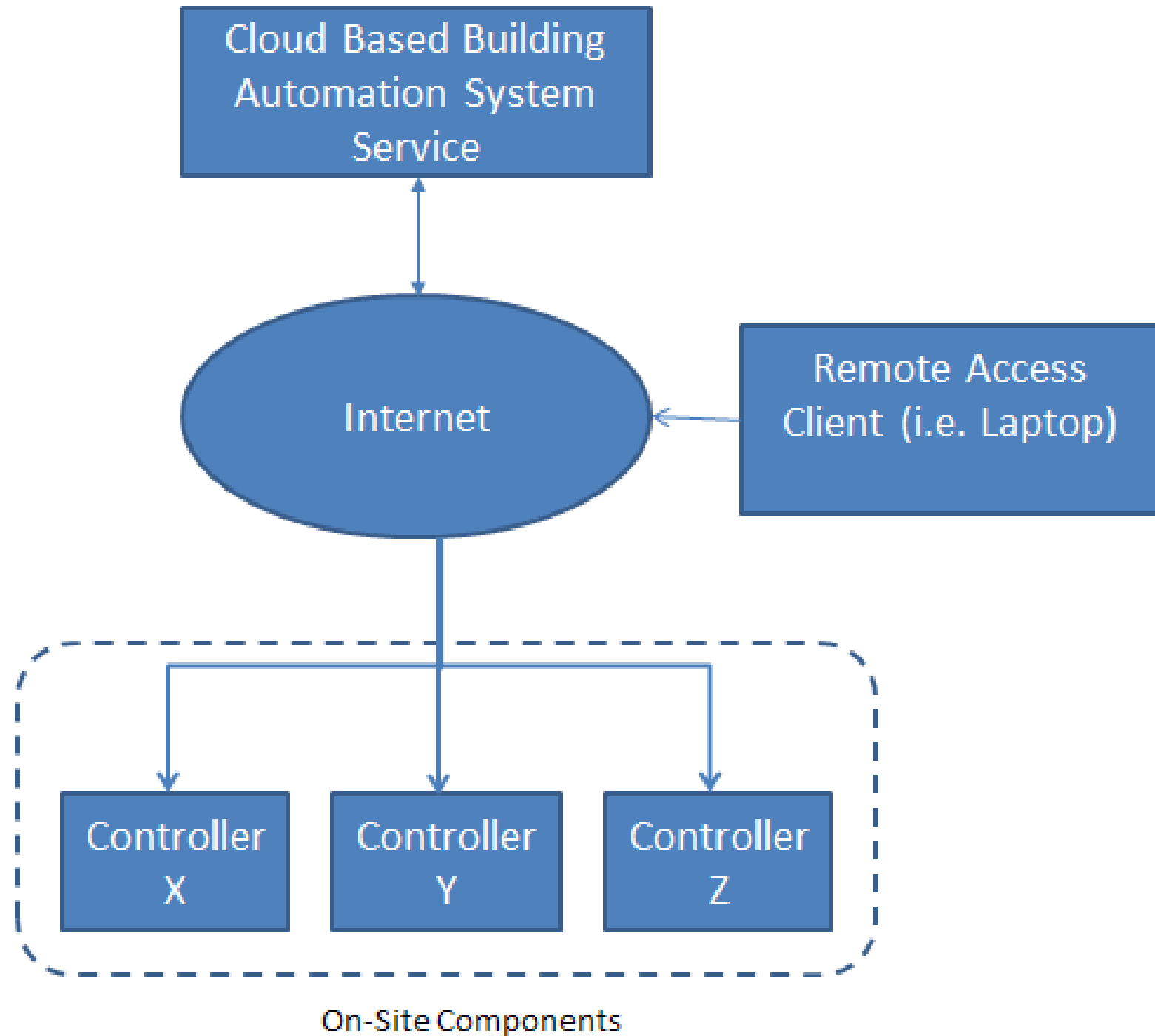
- The future of BAS is cloud-hosted, software-as-a-service (SaaS) solutions
 - Allow for simple integration of new building equipment, deployment of new features & automatic upgrades via the cloud
 - Improved flexibility via open application programming interfaces (APIs)
 - Offer remote access & control to contractors without visiting the site

Cloud-based BAS

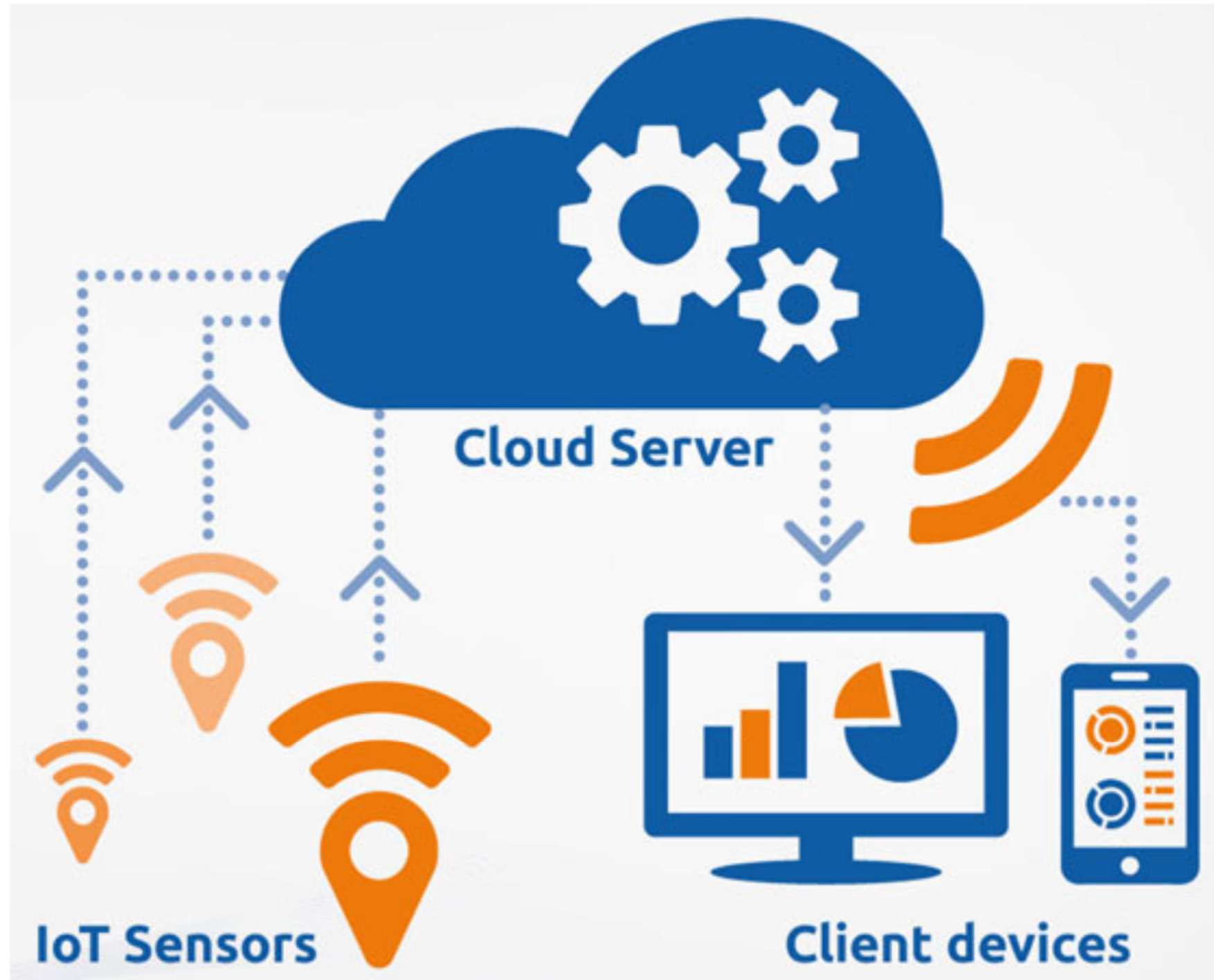


- Cloud-based services also permitted more flexible access to building data
 - Building automation consists of networked sensors & actuators. The systems & how they communicate have been standardized to the point that they can easily connect to many cloud-based services. Smart buildings interact with users & operators, their systems & their environment. Digital twins of buildings & intelligent technologies are giving rise to additional networked services

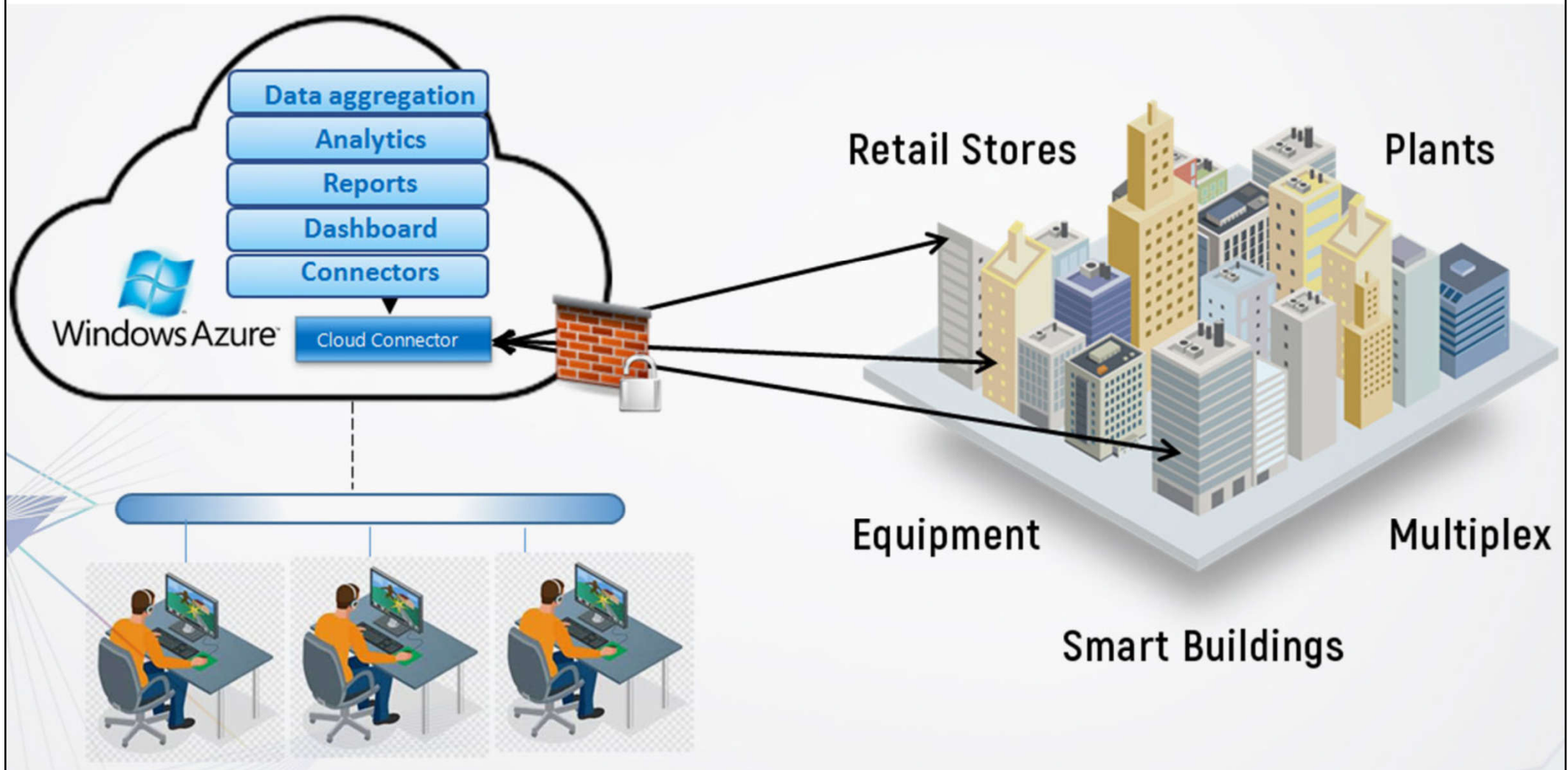
Cloud-based building automation system (BAS) service



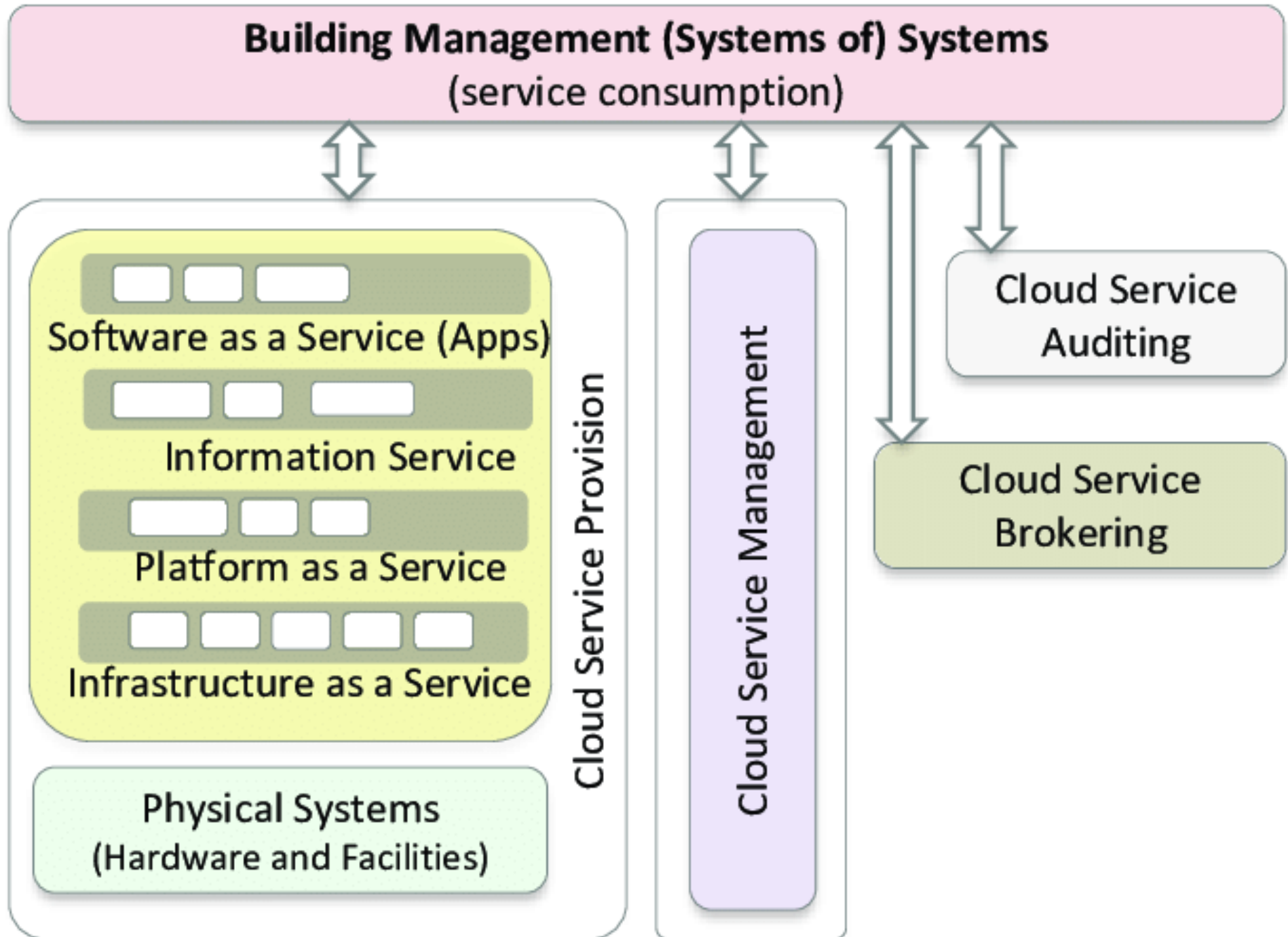
Internet of Things (IoT) & cloud analytics



Cloud platform for smart building automation



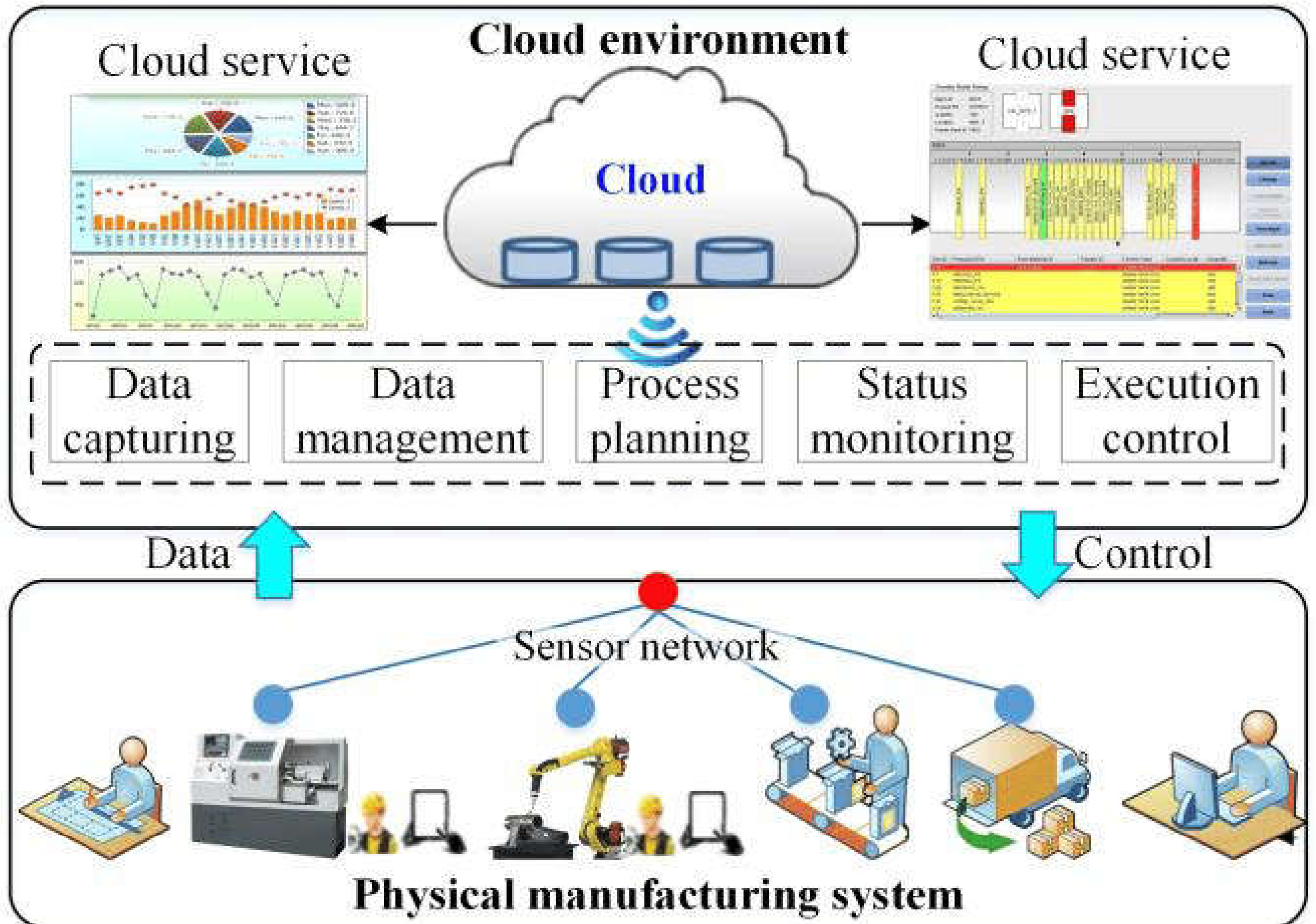
Possible cloud architecture for BAS/BMS



(Source: Noran O., Sota I. & Bernus P., 2019. Towards next generation building management systems, *E3S Web of Conferences*, 111 (20) 05004.

<https://doi.org/10.1051/e3sconf/2019111050>)

Reference to a cloud-based manufacturing system architecture

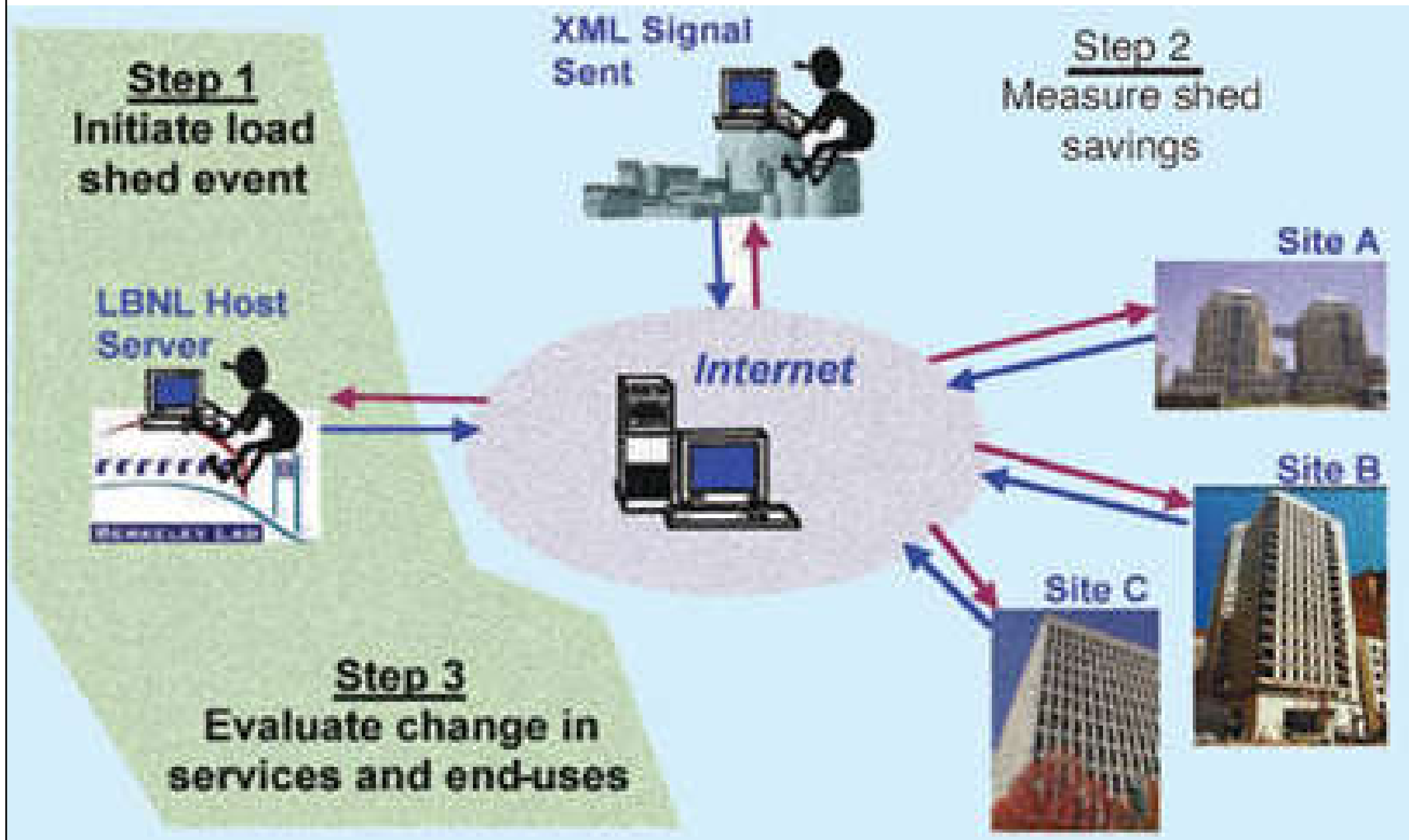


Multi-building solutions



- Facility management for companies with multiple large retail or office locations
- Integrate a BAS/BMS across multiple facilities or locations (multi-site solutions)
 - Consistent data collection at every location
 - Use of IoT & cloud-based BAS
 - Increase ease of use with IoT & cloud-based technologies via mobile apps
 - Customized control through an integrated system

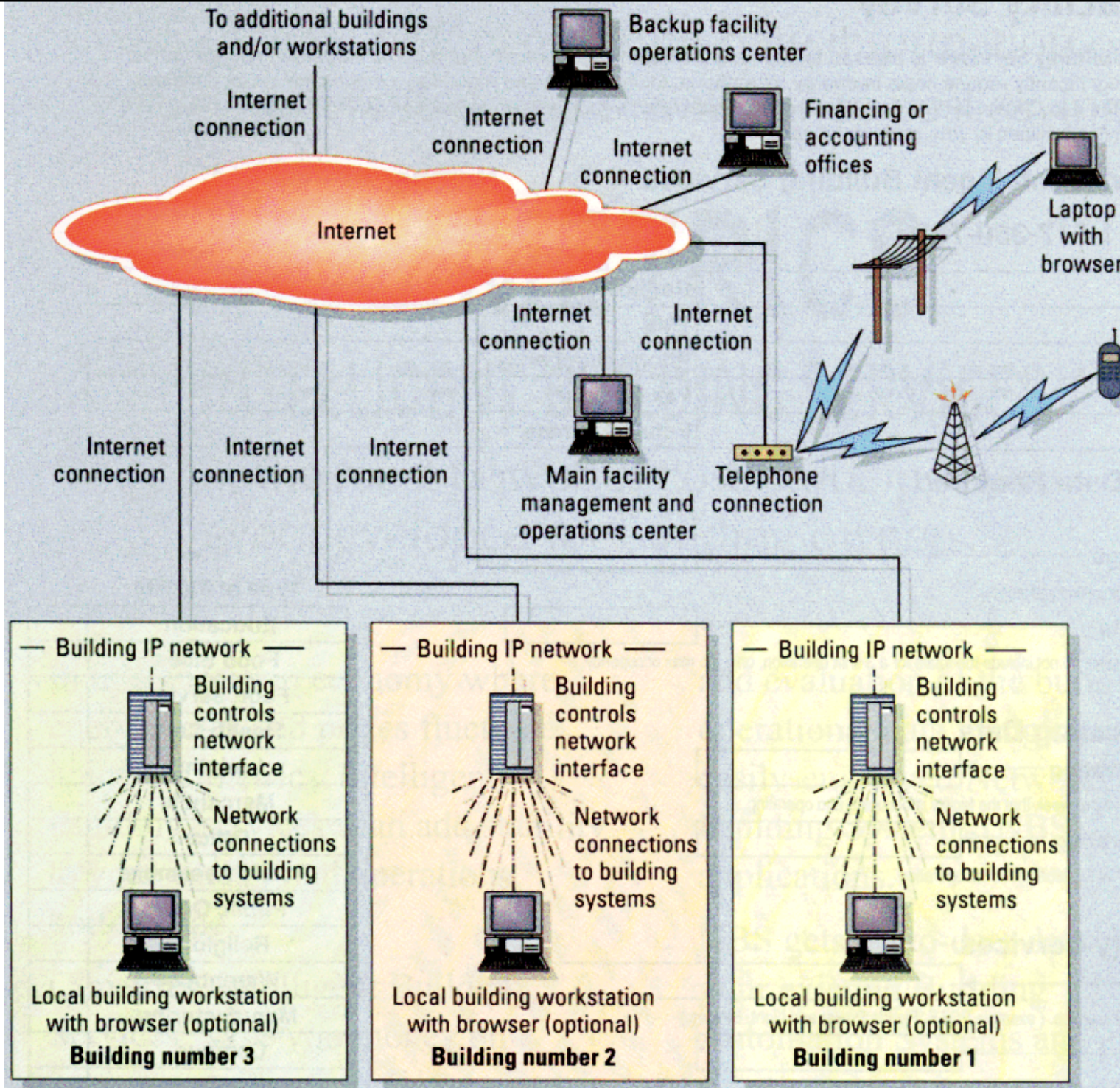
Multi-building Internet demand-response control system



Multi-building solutions



- Multi-building management
 - Benefit: shared O&M resources & expertise
 - Can reduce maintenance costs
 - Internet:- inter-building communication backbone
 - Web browser
 - Less dependent on vendors
- What type(s) of buildings are most suitable?
 - Institutional buildings (e.g. over a campus)
 - Companies with building at different locations



Multi-building management network

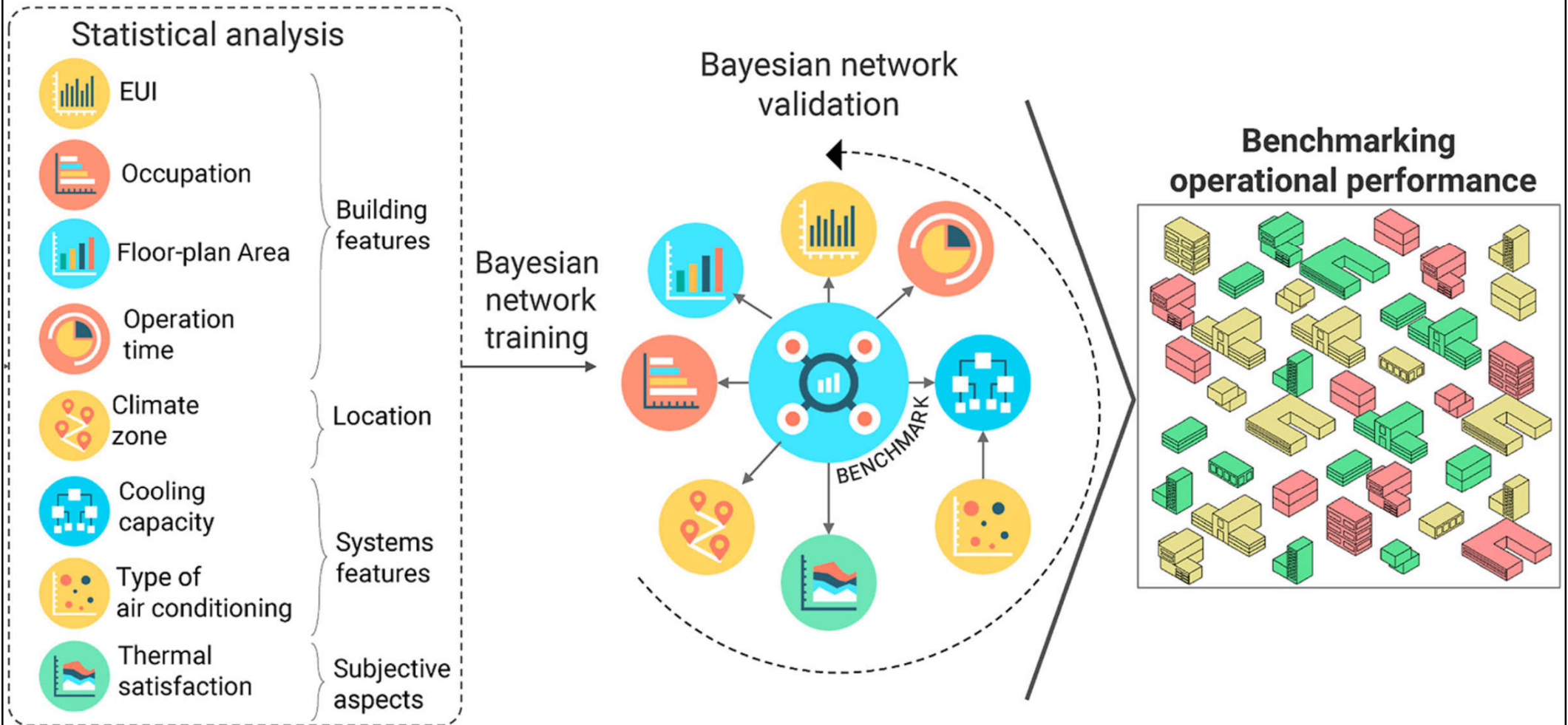
(Source: Hartman, T., 2001. Whole building networks - beyond HVAC, *Network Controls: A Supplement to HPAC Engineering*, May 2001, pp. 36-43.)

Multi-building solutions



- Multi-building energy benchmarking
 - A centralised energy management platform to visualise, monitor and track energy consumption & performance for multiple buildings
 - Apply big data analytics to visualise & analyse energy consumption performance for multiple buildings with real-time energy & sensor data
 - Renewable energy generated by renewable energy systems can also be connected into the platform

Statistical analysis & energy benchmarking of building operating performance for whole-building evaluation

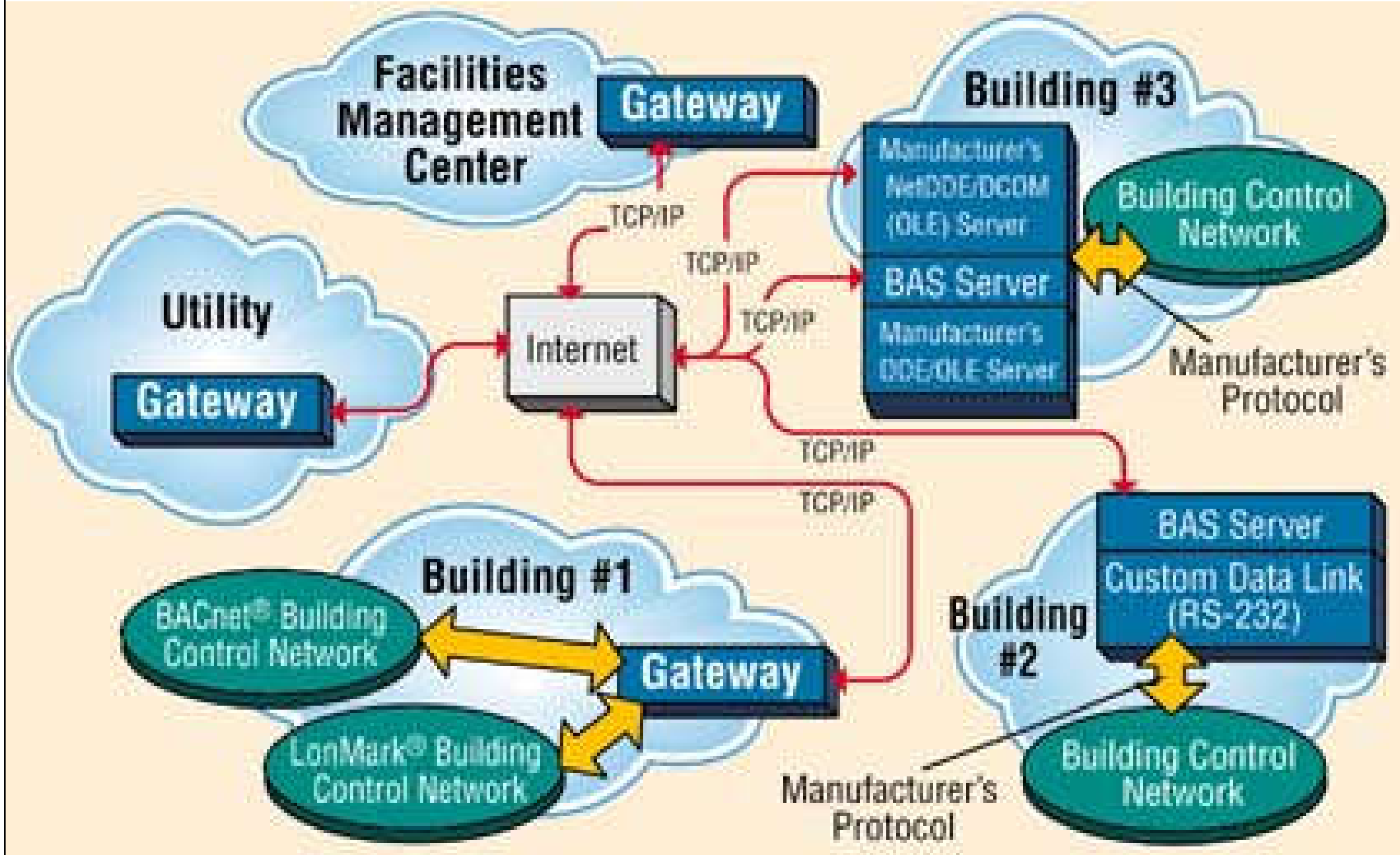


Multi-building solutions



- Challenges of multi-building networks
 - Lack of uniformity w/ individual systems
 - Increase the complexity
 - Some systems need to stand alone in each building
 - Such as fire alarm, security, uninterruptible power supply (UPS)
 - Regulatory & administration practices
 - Fire alarm is often not allowed to be monitored remotely
 - Lack of communication standards

Integration controls network from different buildings

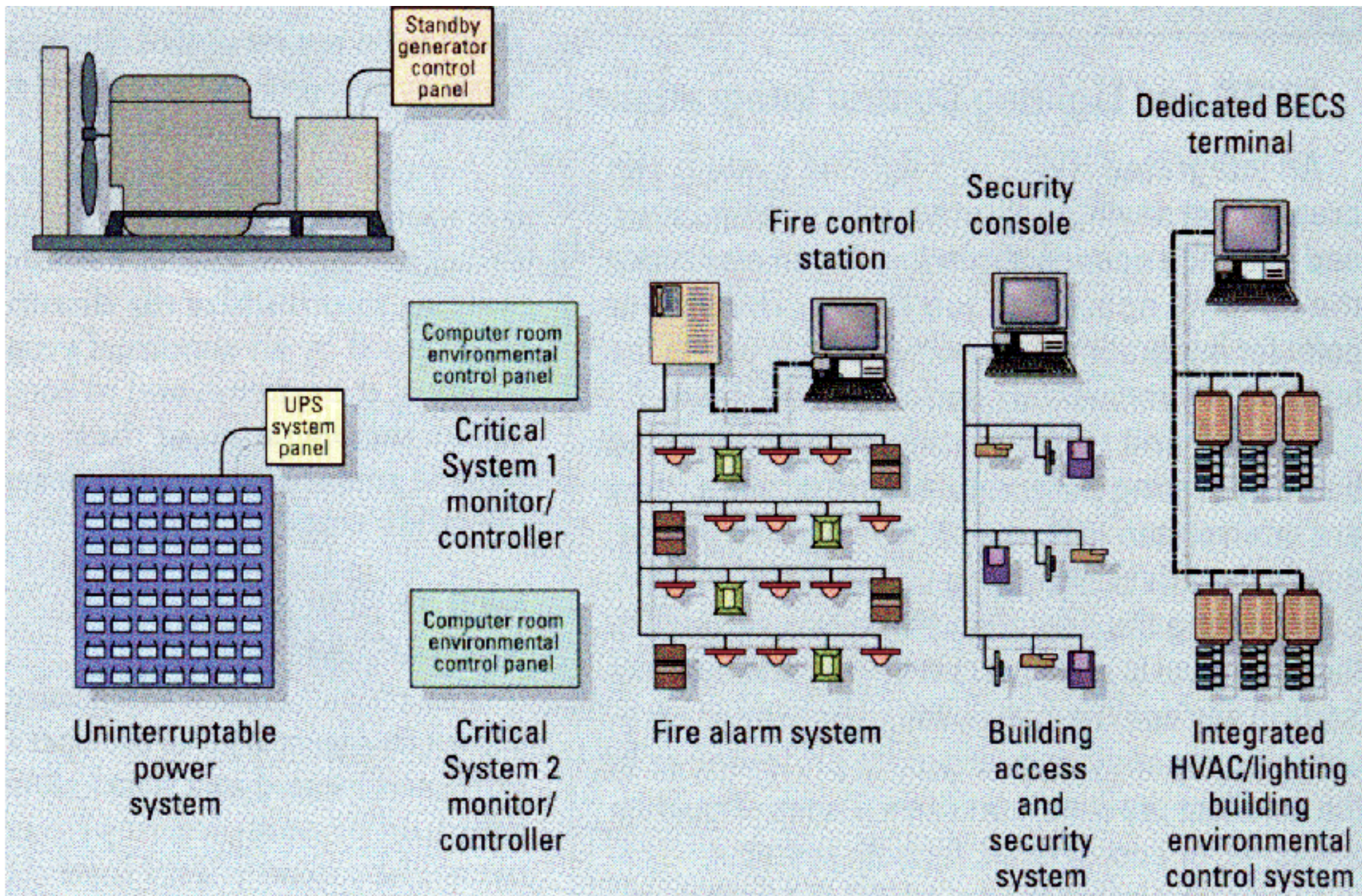


Multi-building solutions

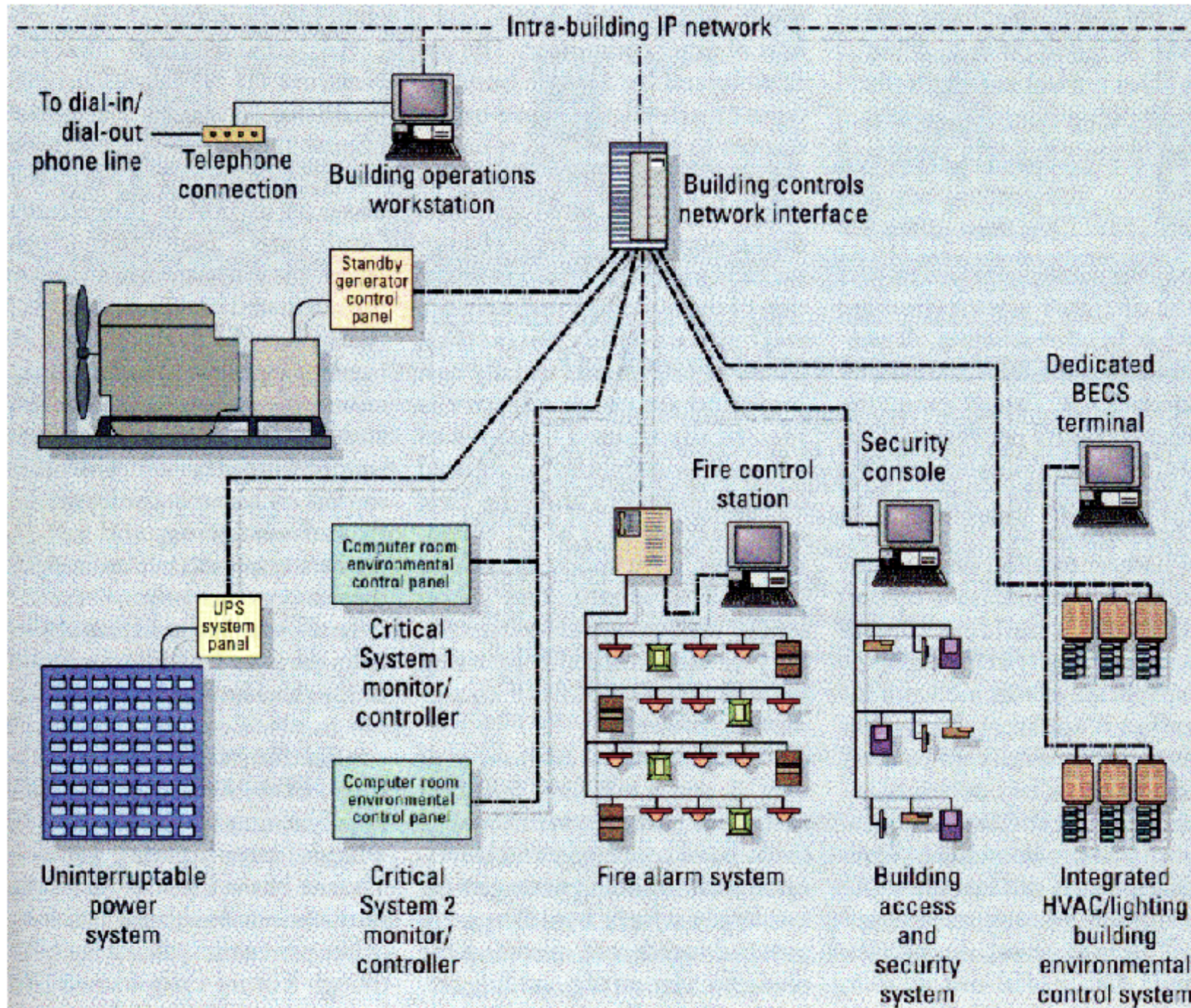


- A single communication is not yet there
 - Interfacing equipment is needed
 - Network interface or ‘gateway’
- Advantages of network integration
 - Everything can be checked at one location
 - Improved reliability on critical systems
 - Only one single modem is needed
 - Benefits of interoperability (e.g. minimise disruption & operation costs)

Isolated sub-systems in a building



Network-based BAS connecting the sub-systems



(Source: Hartman, T., 2001. Whole building networks - beyond HVAC, *Network Controls: A Supplement to HPAC Engineering*, May 2001, pp. 36-43.)



Further Reading

- Connecting BACnet devices into an IP infrastructure
<http://www.automatedbuildings.com/news/mar09/articles/controllers/090220020828ctrls.htm>
- What Is Meant By the term: Internet of Things(IoT)?
<https://medium.com/@kunalmohta/what-is-meant-by-the-term-internet-of-things-iot-287cfc233865>
- The role of IoT in Building Automation Systems
<https://www.zenatix.com/the-role-of-iot-in-building-automation-systems/>
- Cloud-based building automation: building control revolution
<https://buildingenergy.cx-associates.com/2012/11/cloud-based-building-automation-building-control-evolution/>