# Internet Applications

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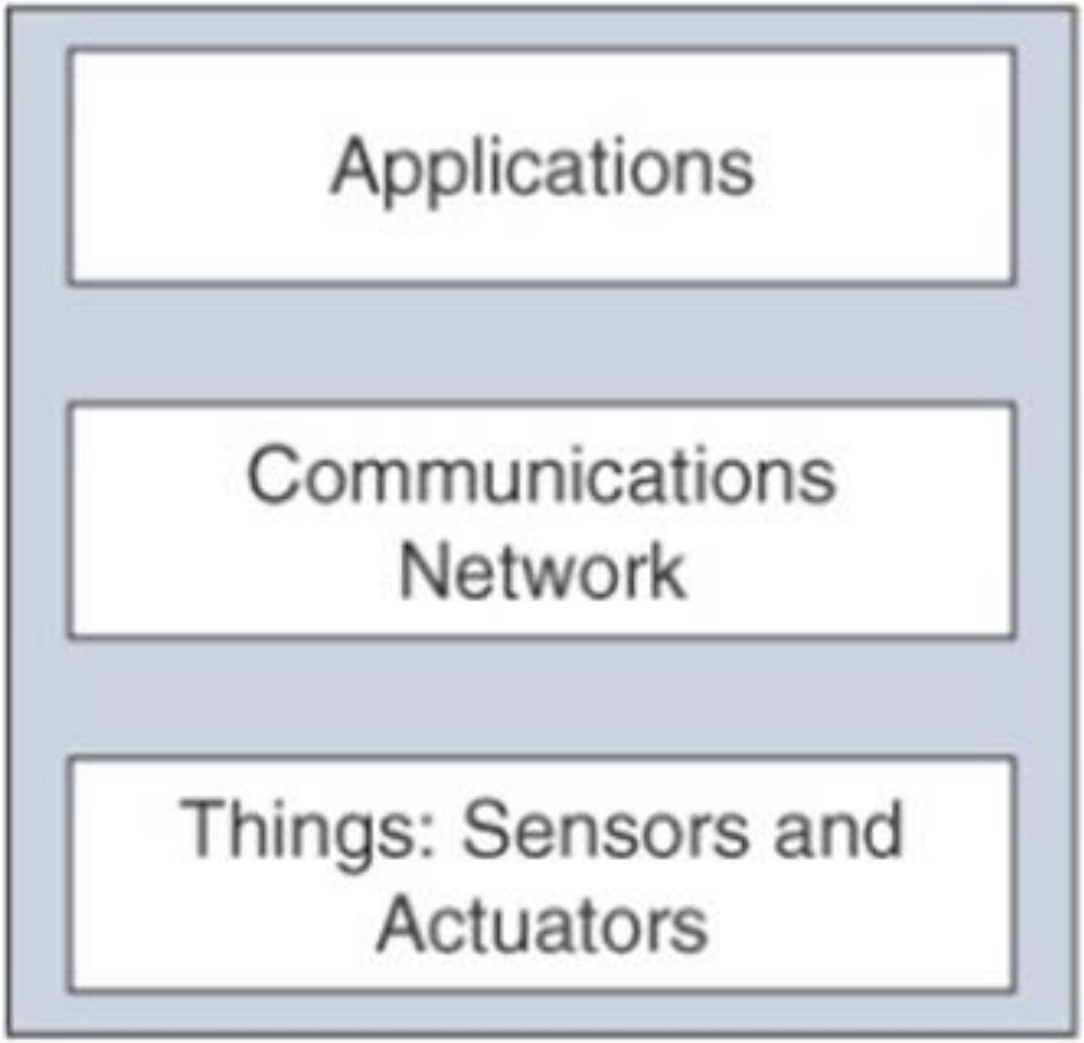
# Chapter 1

# Introduction

# Internet ofThings

# Core IoT Functional Stack



**Layer 2: Communications Network Layer:** Once you have determined the influence of the smart object form factor over its transmission capabilities (transmission range, data volume and frequency, sensor density and mobility), you are ready to connect the object and communicate. Compute and network assets used in IoT can be very different from those in IT environments.

The difference in the physical form factors between devices used by IT and OT is obvious even to the most casual of observers. What typically drives this is the physical environment in which the devices are deployed. What may not be as inherently obvious, however, is their operational differences. The operational differences must be understood in order to apply the correct handling to secure the target assets.

# IT

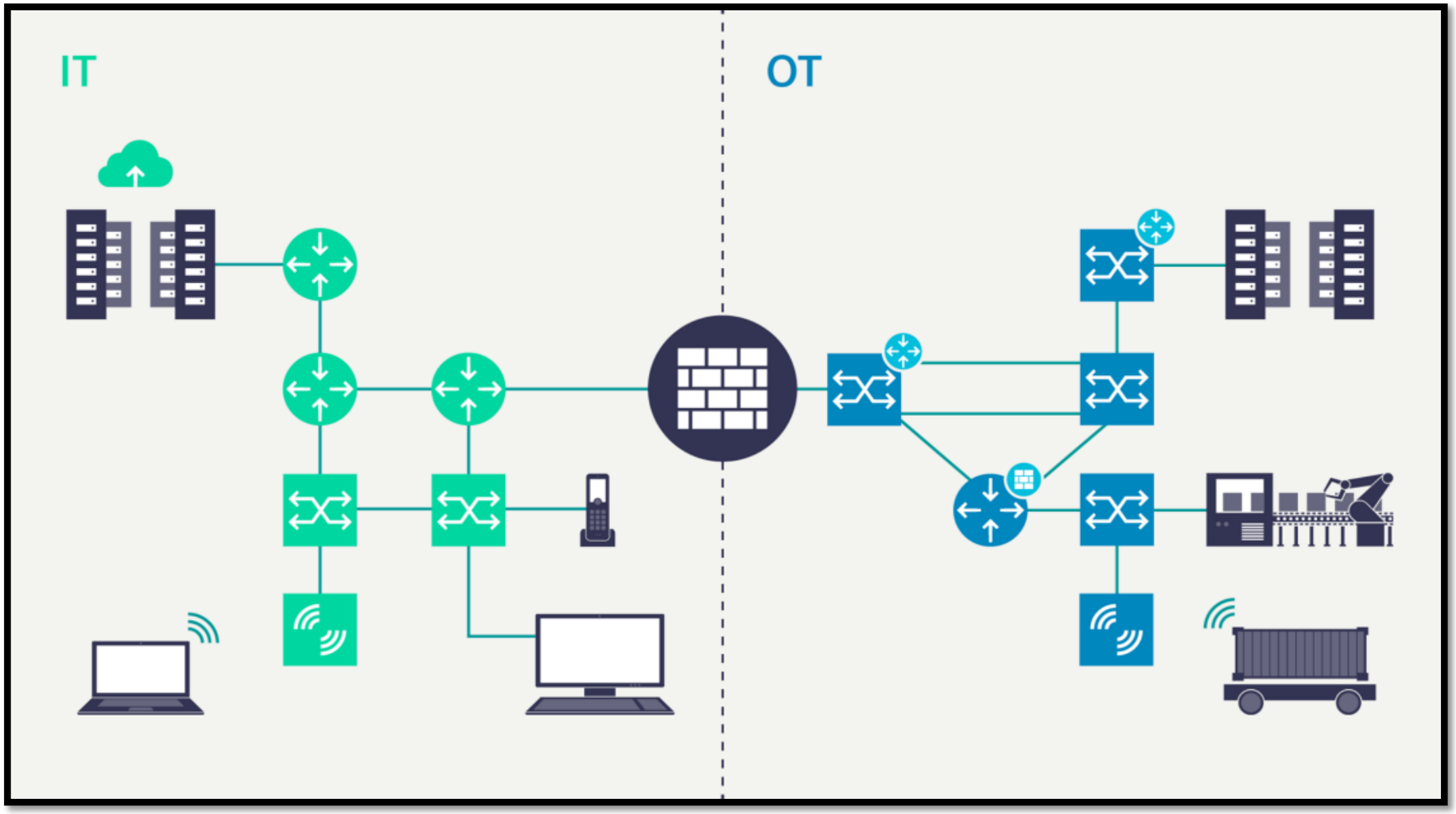
Data and the flow
of digital information

# OT

Operation of physical processes
and the machinery used
to carry them out

Hazardous location design may also cause corrosive impact to the equipment. Caustic materials can impact connections over which power or communications travel. Furthermore, they can result in reduced thermal efficiency by potentially coating the heat transfer surfaces. In some scenarios, the concern is not how the environment can impact the equipment but how the equipment can impact the environment.

In contrast to most IT-based systems, industrial compute systems often transmit their state or receive inputs from external devices through an alarm channel. These may drive an indicator light (stack lights) to display the status of a process element from afar. This same element can also receive inputs to initiate actions within the system itself. Power supplies in OT systems are also frequently different from those commonly seen on standard IT equipment.


IT
OT

A wider range of power variations are common attributes of industrial compute components. DC power sources are also common in many environments. Given the criticality of many systems, it is often required that redundant power supplies be built into the device itself. Extraneous power supplies, especially those not inherently mounted, are frowned upon, given the potential for accidental unplugging. In some utility cases, the system must be able to handle brief power outages and still continue to operate.

# Communications Network Layer

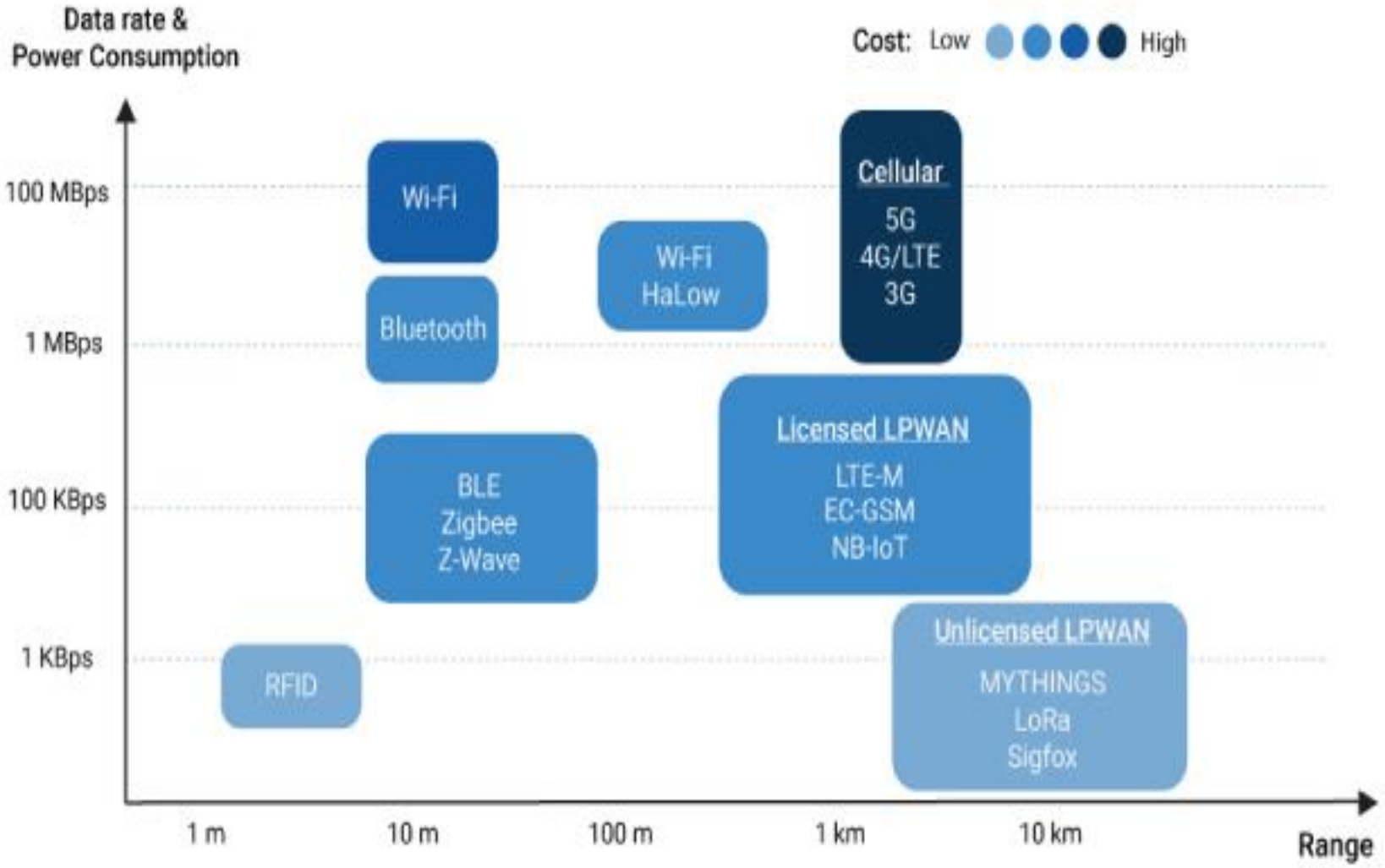
4- IoT Network Management Sublayer

3- Network Transport Sublayer

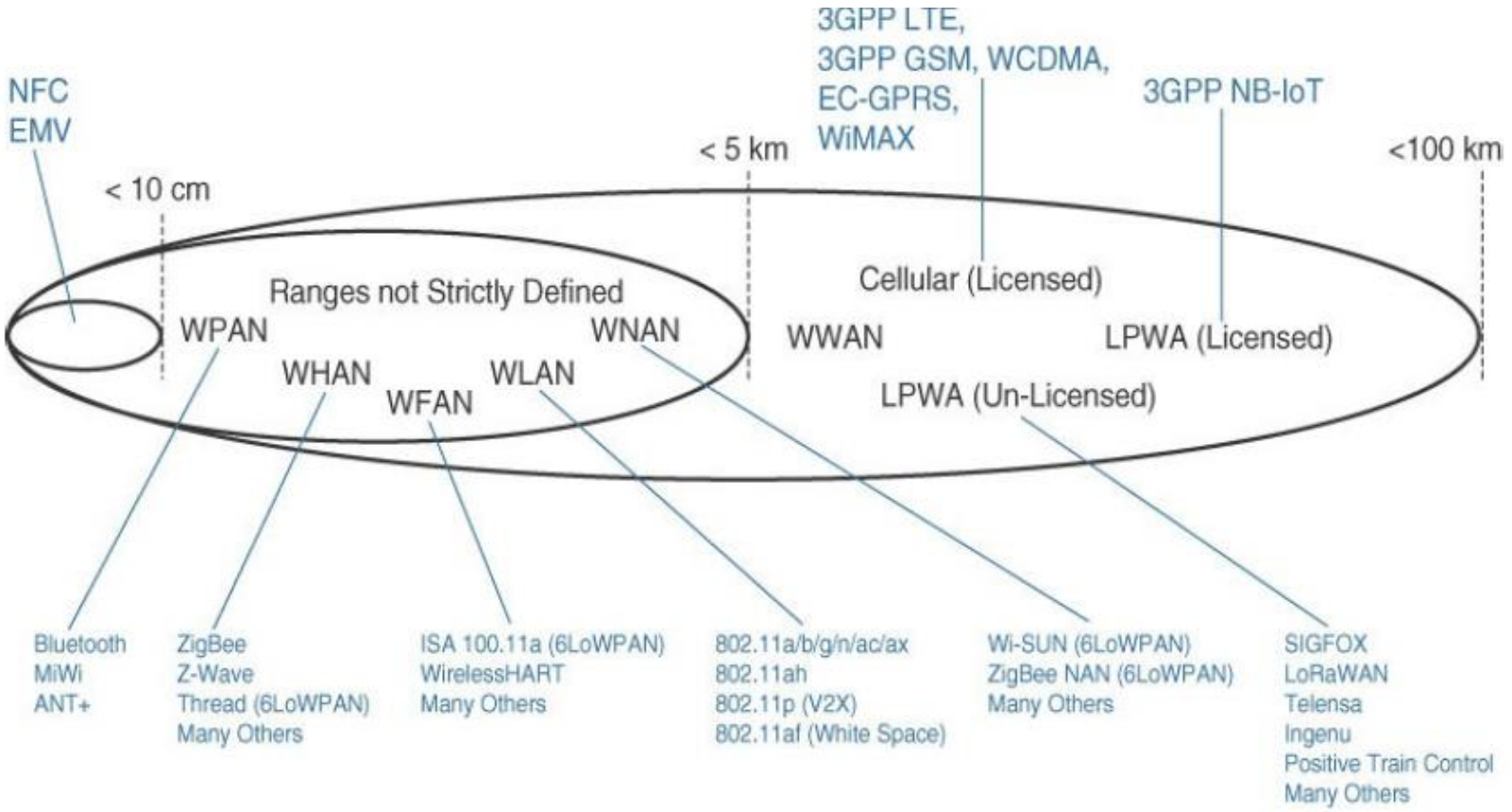
2- Gateways and Backhaul Sublayer

1- Access Network Sublayer

**A) Access Network Sublayer** There is a direct relationship between the IoT network technology you choose and the type of connectivity topology this technology allows. Each technology was designed with a certain number of use cases in mind (what to connect, where to connect, how much data to transport at what interval and over what distance). These use cases determined the frequency band that was expected to be most suitable, the frame structure matching the expected data pattern (packet size and communication intervals), and the possible topologies that these use cases illustrate.


Data rate &
Power Consumption
Cost: Low High
100 MBps
1 MBps
100 KBps
1 KBps
Wi-Fi
Bluetooth
Wi-Fi
HaLow
Cellular
5G
4G/LTE
3G
BLE
Zigbee
Z-Wave
Licensed LPWAN
LTE-M
EC-GSM
NB-IoT
RFID
Unlicensed LPWAN
MYTHINGS
LoRa
Sigfox
1 m
10 m
100 m
1 km
10 km
Range

As IoT continues to grow exponentially, you will encounter a wide variety of applications and special use cases. For each of them, an access technology will be required. IoT sometimes reuses existing access technologies whose characteristics match more or less closely the IoT use case requirements. Whereas some access technologies were developed specifically for IoT use cases, others were not. One key parameter determining the choice of access technology is the range between the smart object and the information collector.




WPAN: Wireless Personal Area Network
WHAN: Wireless Home Area Network
WFAN: Wireless Field (or Factory) Area Network
WLAN: Wireless Local Area Network

WNAN: Wireless Neighborhood Area Network
WWAN: Wireless Wide Area Network
LPWA: Low Power Wide Area

*Access Technologies and Distances*

Note that the ranges are inclusive. For example, cellular is indicated for transmissions beyond 5 km, but you could achieve a successful cellular transmission at shorter range (for example, 100 m). By contrast, ZigBee is expected to be efficient over a range of a few tens of meters, but you would not expect a successful ZigBee transmission over a range of 10 km.

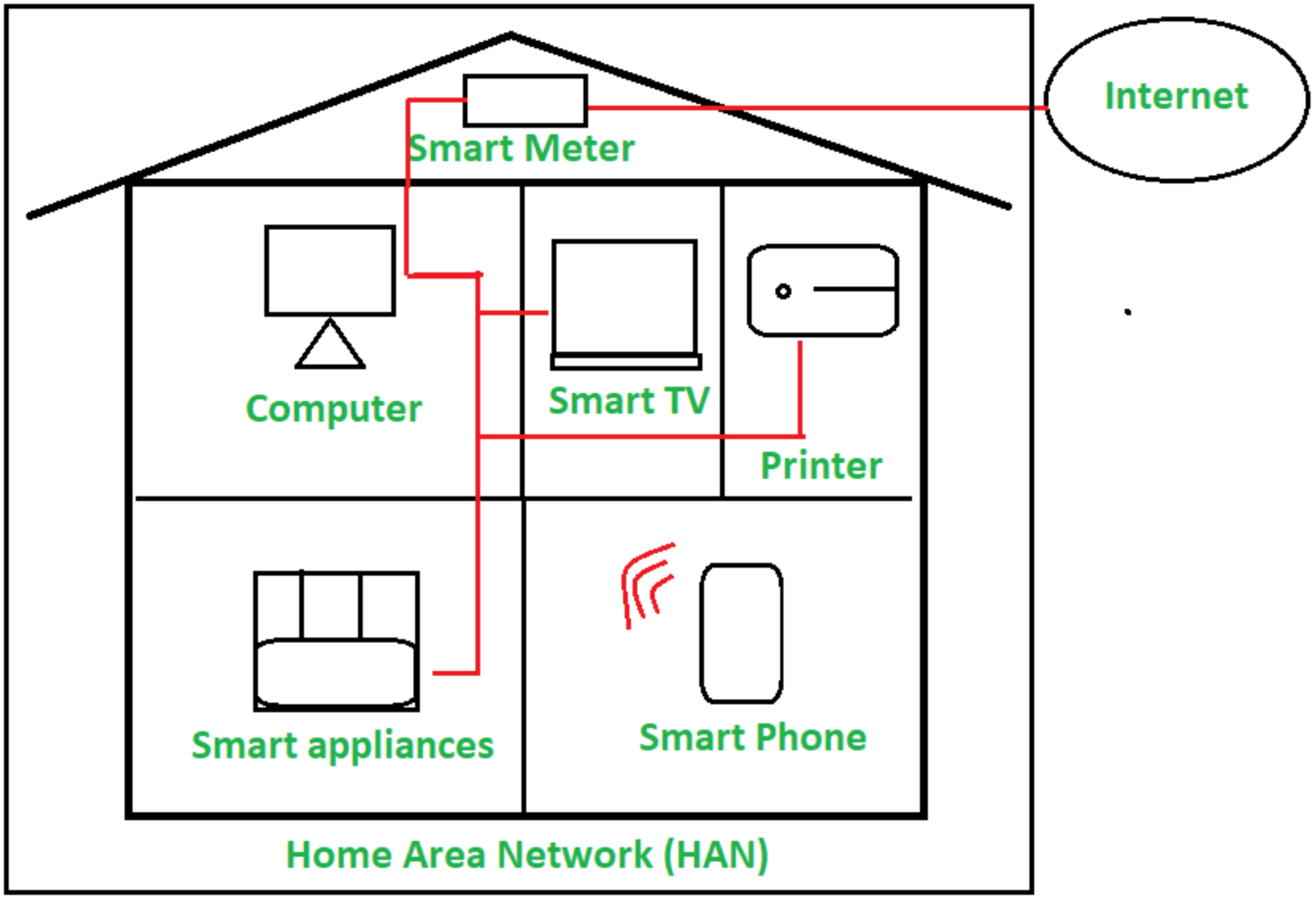
Range estimates are grouped by category names that illustrate the environment or the vertical where data collection over that range is expected. Common groups are as follows:

**PAN (Personal Area Network):** Scale of a few meters. This is the personal space around a person. A common wireless technology for this scale is Bluetooth.

# Personal Area Network

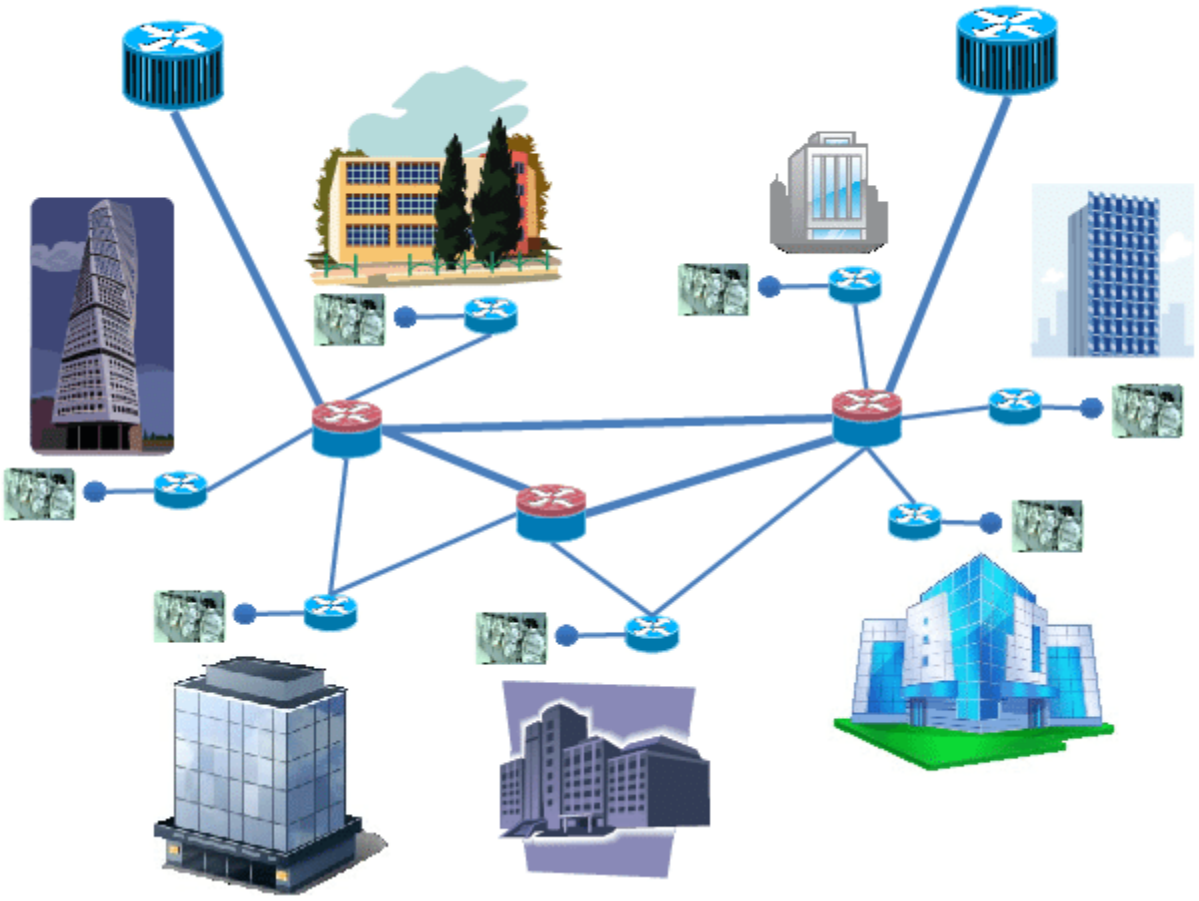
**HAN (Home Area Network):** Scale of a few tens of meters. At this scale, common wireless technologies for IoT include ZigBee and Bluetooth Low Energy (BLE).

**NAN (Neighborhood Area Network):** Scale of a few hundreds of meters. The term NAN is often used to refer to a group of house units from which data is collected.


Internet
Smart Meter
Computer
Smart TV
Printer
Smart appliances
Smart Phone
Home Area Network (HAN)

**FAN (Field Area network):** Scale of several tens of meters to several hundred meters. FAN typically refers to an outdoor area larger than a single group of house units. The FAN is often seen as "open space" (and therefore not secured and not controlled). A FAN is sometimes viewed as a group of NANs, but some verticals see the FAN as a group of HANs or a group of smaller outdoor cells. As you can see, FAN and NAN may sometimes be used interchangeably. In most cases, the vertical context is clear enough to determine the grouping hierarchy.

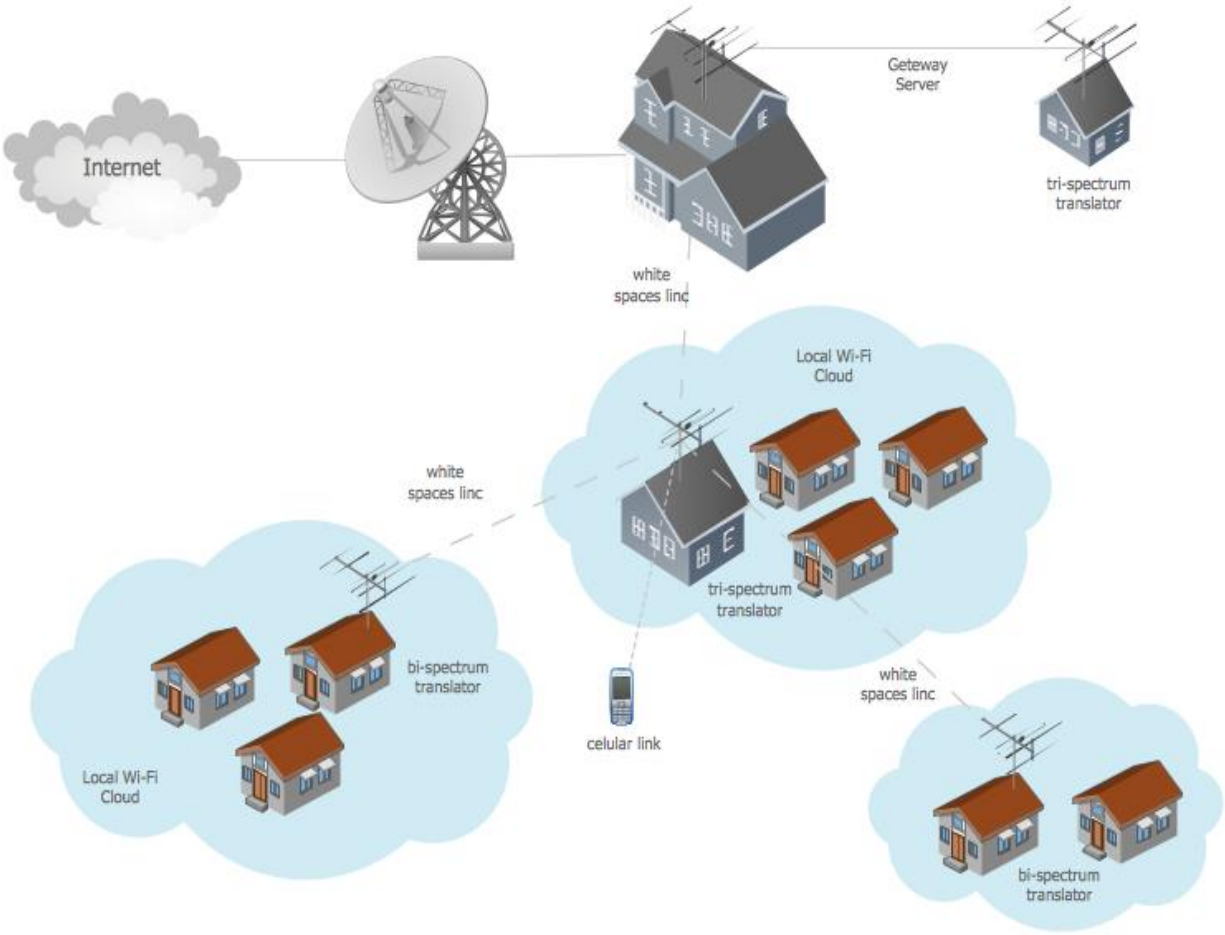
# Neighborhood Area Network



**LAN (local area network):** Scale of up to 100 m. This term is very common in networking, and it is therefore also commonly used in the IoT space when standard networking technologies (such as Ethernet or IEEE 802.11) are used. Other networking classifications, such as **MAN** (metropolitan area network, with a range of up to a few kilometers) and **WAN** (wide area network, with a range of more than a few kilometers), are also commonly used.

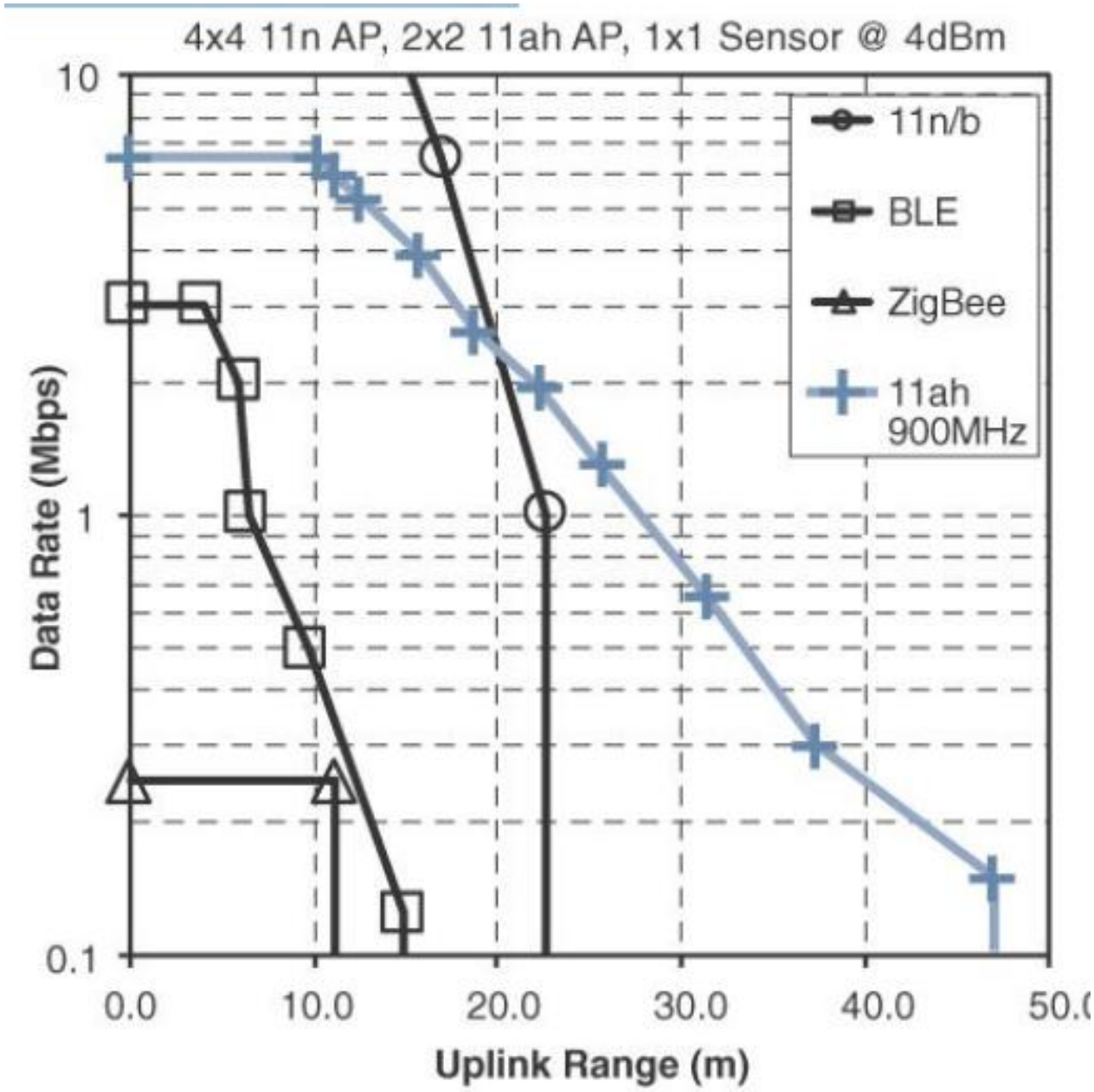
Note that for all these places in the IoT network, a "**W**" can be added to specifically indicate wireless technologies used in that space. For example, HomePlug is a wired technology found in a HAN environment, but a HAN is often referred to as a WHAN (wireless home area network) when a wireless technology, like ZigBee, is used in that space.

# Wide Area Network



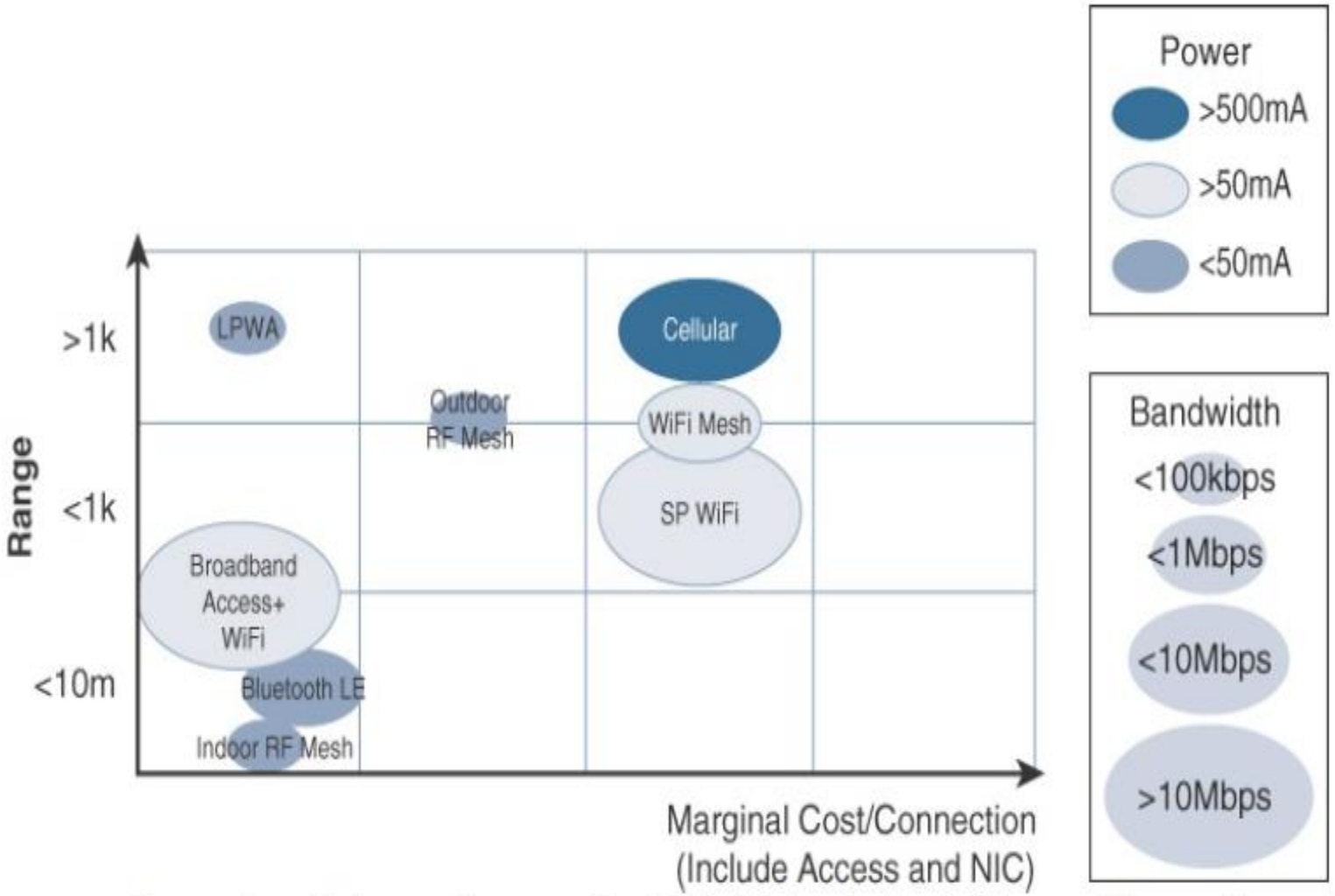
Similar achievable distances do not mean similar protocols and similar characteristics. Each protocol uses a specific frame format and transmission technique over a specific frequency (or band). These characteristics introduce additional differences. For example, four technologies representing WHAN to WLAN ranges and compares the throughput and range that can be achieved in each case.

The sensor uses the same frame size, transmit power, and antenna gain. The slope of throughput degradation as distance increases varies vastly from one technology to the other. This difference limits the amount of data throughput that each technology can achieve as the distance from the sensor to the receiver increases.


4x4 11n AP, 2x2 11ah AP, 1x1 Sensor @ 4dBm
10
1
0.1
Data Rate (Mbps)
0.0
10.0
20.0
30.0
40.0
50.0
Uplink Range (m)
11n/b
BLE
ZigBee
11ah
900MHz

Increasing the throughput and achievable distance typically comes with an increase in power consumption. Therefore, after determining the smart object requirements (in terms of mobility and data transfer), a second step is to determine the target quantity of objects in a single collection cell, based on the transmission range and throughput required. This parameter in turn determines the size of the cell. It may be tempting to simply choose the technology with the longest range and highest throughput.

However, the cost of the technology is a third determining factor. Figure combines cost, range, power consumption, and typical available bandwidth for common IoT access technologies. The amount of data to carry over a given time period along with correlated power consumption (driving possible limitations in mobility and range) determines the wireless cell size and structure. Similar ranges also do not mean similar topologies.



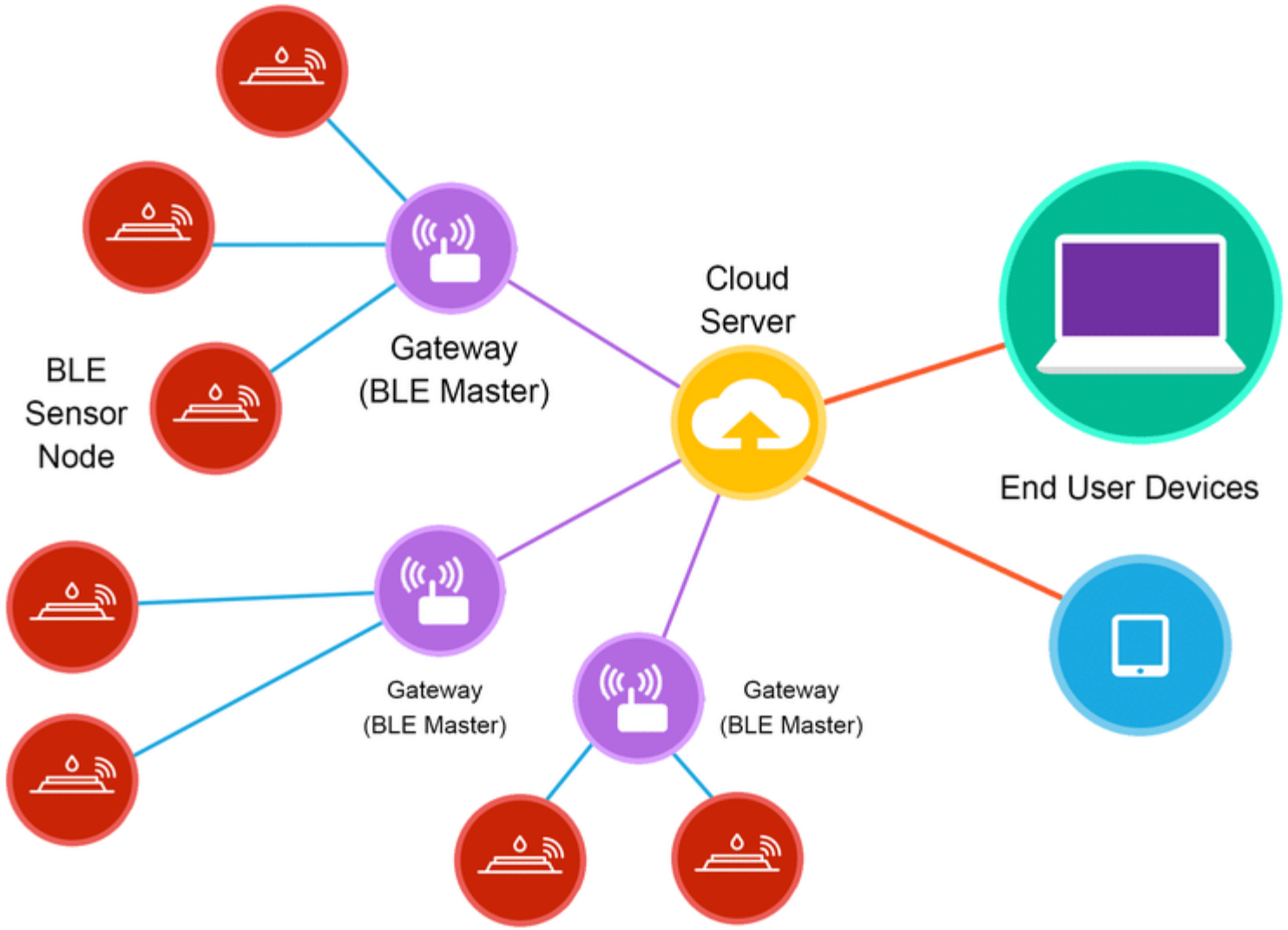

*Comparison Between Common Last-Mile Technologies in Terms of Range Versus Cost, Power, and Bandwidth*

Some technologies offer flexible connectivity structure to extend communication possibilities:

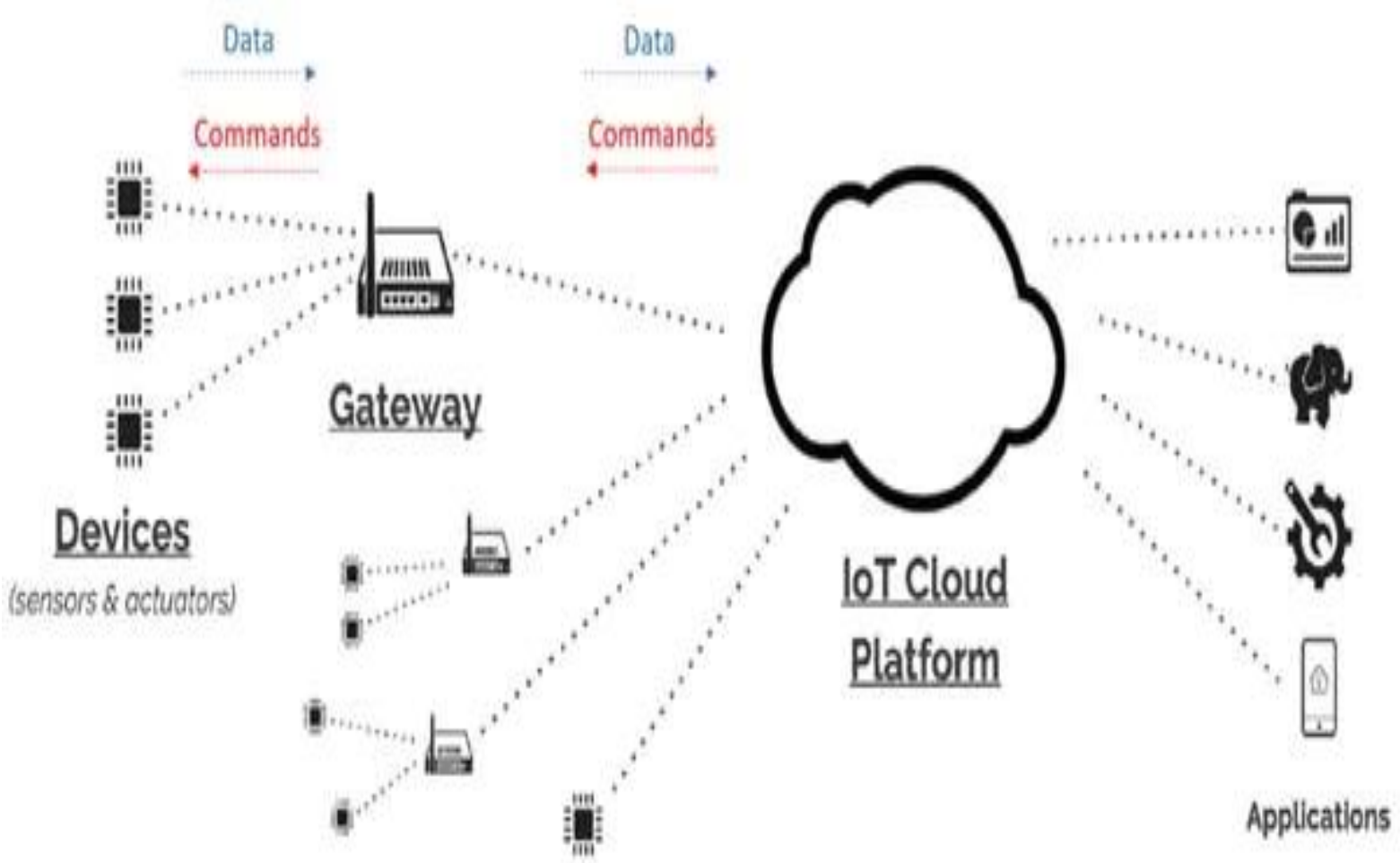
- Point-to-point topologies: These topologies allow one point to communicate with another point. This topology in its strictest sense is uncommon for IoT access, as it would imply that a single object can communicate only with a single gateway. However, several technologies are referred to as "point-to-point" when each object establishes an individual session with the gateway. The "point-to point" concept, in that case, often refers to the communication structure more than the physical topology.

Point-to-Point topology

- Point-to-multipoint topologies: These topologies allow one point to communicate with more than one other point. Most IoT technologies where one or more than one gateways communicate with multiple smart objects are in this category. However, depending on the features available on each communicating mode, several subtypes need to be considered.

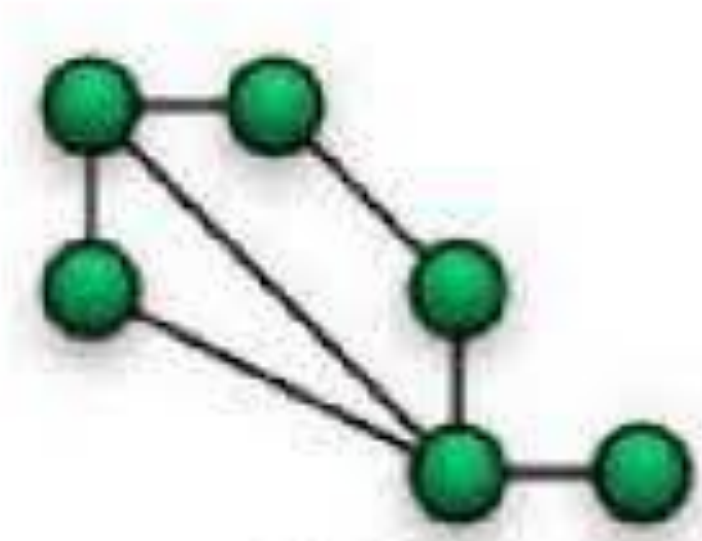

BLE
Sensor
Node
Gateway
(BLE Master)
Cloud
Server
End User Devices
Gateway
(BLE Master)
Gateway
(BLE Master)

A particularity of IoT networks is that some nodes (for example, sensors) support both data collection and forwarding functions, while some other nodes (for example, some gateways) collect the smart object data, sometimes instruct the sensor to perform specific operations, and also interface with other networks or possibly other gateways. For this reason, some technologies categorize the nodes based on the functions (described by a protocol) they implement.


Data
Commands
Data
Commands
Gateway
Devices
(sensors & actuators)
IoT Cloud
Platform
Applications

To form a network, a device needs to connect with another device. When both devices fully implement the protocol stack functions, they can form a peer-to-peer network. However, in many cases, one of the devices collects data from the others. For example, in a house, temperature sensors may be deployed in each room or each zone of the house, and they may communicate with a central point where temperature is displayed and controlled. A room sensor does not need to communicate with another room sensor. In that case, the control point is at the center of the network. The network forms a star topology, with the control point at the hub and the sensors at the spokes.

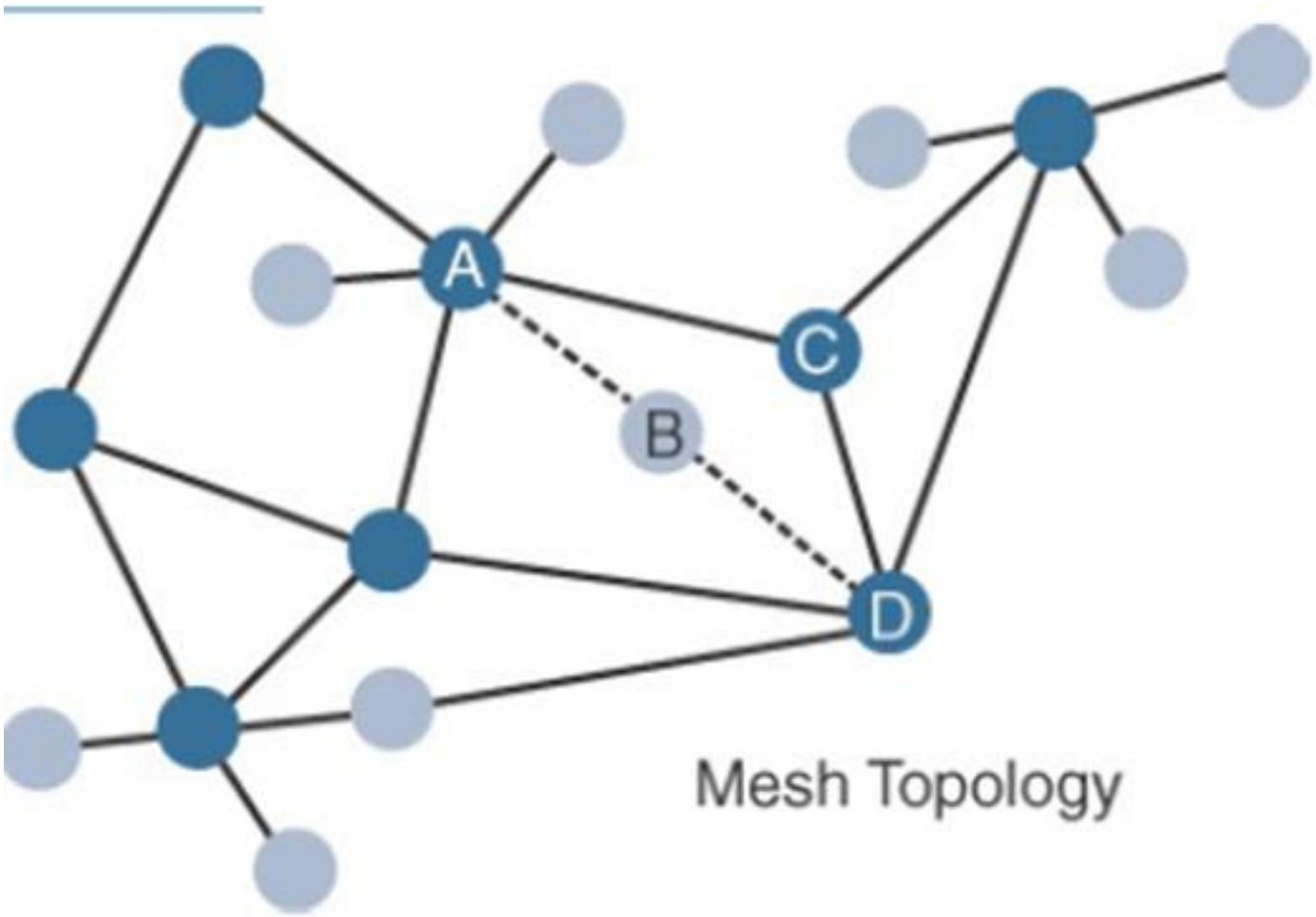
Other **point-to-multipoint technologies** allow a node to have more than one path to another node, forming a mesh topology. This redundancy means that each node can communicate with more than just one other node. This communication can be used to directly exchange information between nodes (the receiver directly consumes the information received) or to extend the range of the communication link. In this case, an intermediate node acts as a relay between two other nodes.



Mesh

Star

An example of a technology that implements a mesh topology is Wi-Fi mesh. Another property of mesh networks is redundancy. The disappearance of one node does not necessarily interrupt network communications. Data may still be relayed through other nodes to reach the intended destination. shows a mesh topology. Nodes A and D are too far apart to communicate directly. In this case, communication can be relayed through nodes B or C. Node B may be used as the primary relay. However, the loss of node B does not prevent the communication between nodes A and D. Here, communication is rerouted through another node, node C.

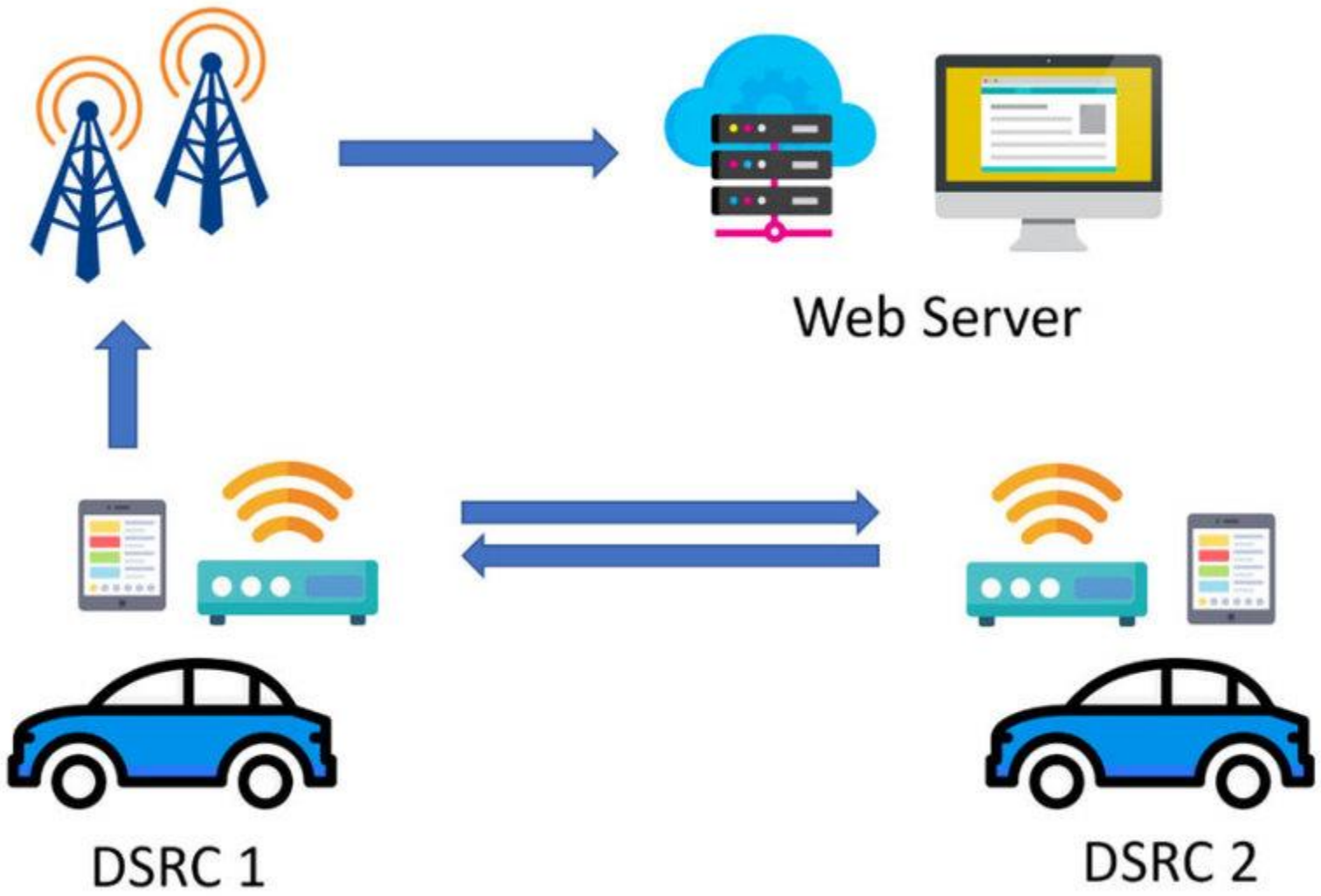



Mesh Topology

**B- Gateways and Backhaul Sublayer:** Data collected from a smart object may need to be forwarded to a central station where data is processed. As this station is often in a different location from the smart object, data directly received from the sensor through an access technology needs to be forwarded to another medium (the backhaul) and transported to the central station. The gateway is in charge of this inter-medium communication.

In most cases, the smart objects are static or mobile within a limited area. The gateway is often static. However, some IoT technologies do not apply this model. For example, **dedicated short-range communication (DSRC)** allows vehicle-to-vehicle and vehicle-to-infrastructure communication. In this model, the smart object's position relative to the gateway is static. The car includes sensors and one gateway. Communication between the sensors and the gateway may involve wired or wireless technologies.

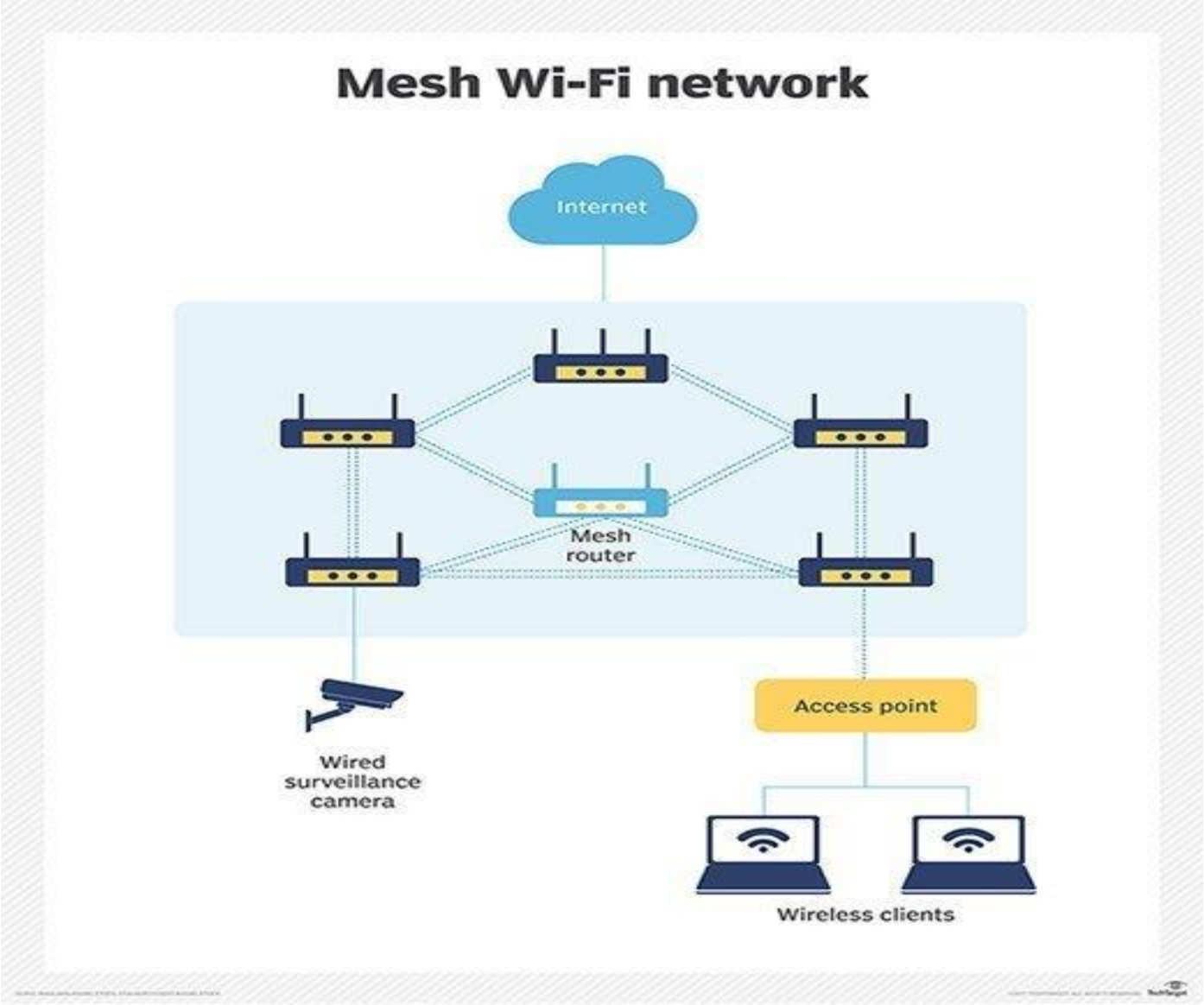
**Dedicated Short-range Communication (DSRC)** is a wireless communication technology designed to allow automobiles in the intelligent transportation system (ITS) to communicate with other automobiles or infrastructure technology. DSRC technology operates on the 5.9 GHz band of the radio frequency spectrum and is effective over short to medium distances.


Web Server
DSRC 1
DSRC 2

Sensors may also be integrated into the road infrastructure and connect over a wired or wireless technology to a gateway on the side of the road. A wireless technology (DSRC operates in the upper 5 GHz range) is used for backhaul communication, peer-to-peer, or mesh communication between vehicles.

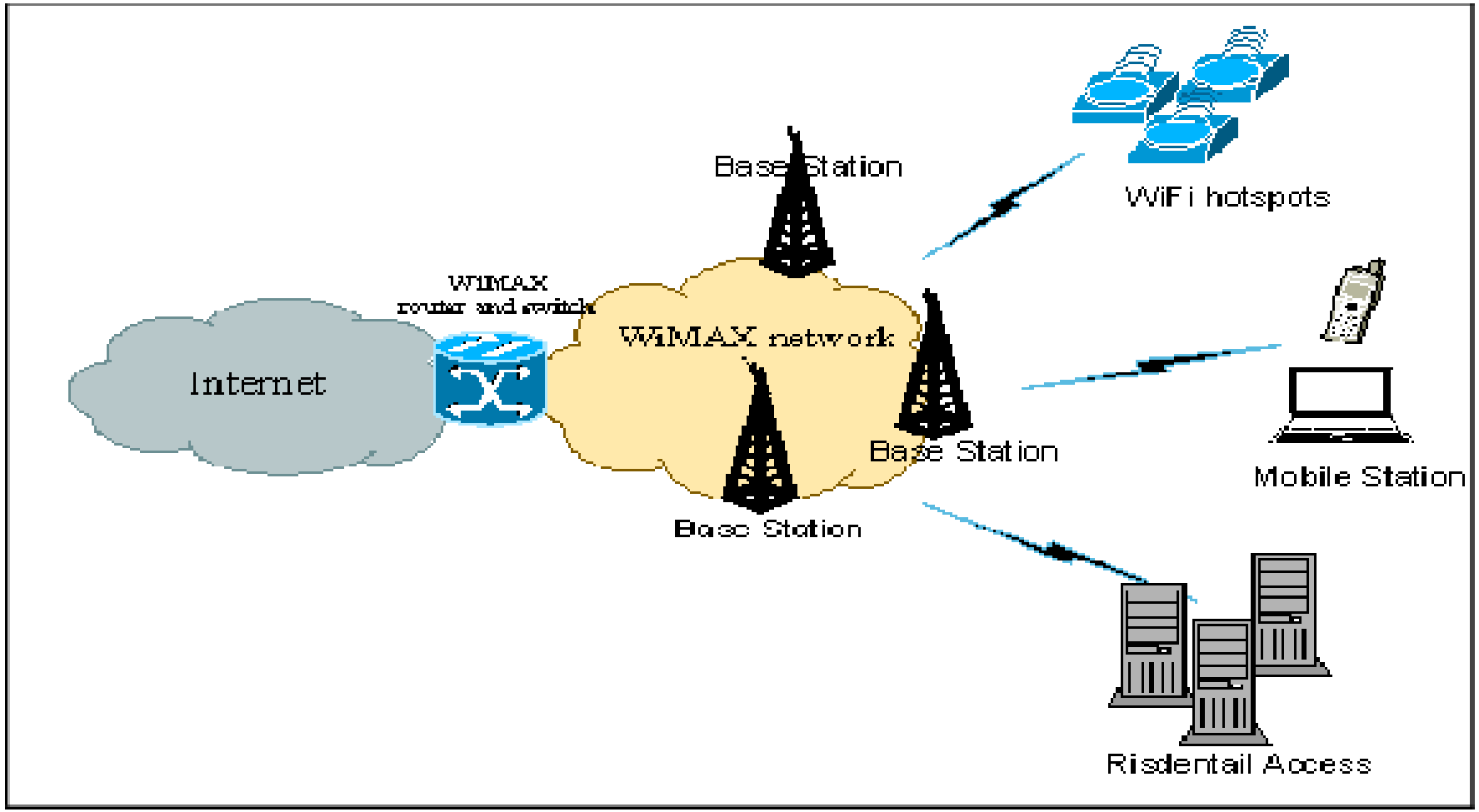
In the **DSRC case**, the entire "sensor field" is moving along with the gateway, but the general principles of IoT networking remain the same. The range at which DSRC can communicate is limited. Similarly, for all other IoT architectures, the choice of a backhaul technology depends on the communication distance and also on the amount of data that needs to be forwarded. When the smart object's operation is controlled from a local site, and when the environment is stable (for example, factory or oil and gas field), Ethernet can be used as a backhaul.

In unstable or changing environments (for example, open mines) where cables cannot safely be run, a wireless technology is used. Wi-Fi is common in this case, often with multiple hops between the sensor field and the operation center. Mesh is a common topology to allow communication flexibility in this type of dynamic environment.


Mesh Wi-Fi network
Internet
Mesh
router
Wired
surveillance
camera
Access point
Wireless clients

However, throughput decreases as node-to-node distance increases, and it also decreases as the number of hops increases. In a typical Wi-Fi mesh network, throughput halves for each additional hop. Some technologies, like 802.11ah, implement Wi-Fi in a lower band (lower than 1 GHz instead of 2.4 GHz/5 GHz for classical Wi-Fi) with special provisions adapted to IoT, to achieve a longer range (up to about 2 km). Beyond that range, other technologies are needed.

**WiMAX (802.16)** is an example of a longer-range technology. WiMAX can achieve ranges of up to 50 kilometers with rates of up to 70 Mbps. Obviously, you cannot achieve maximum rate at maximum range; you could expect up to 70 Mbps at short range and 2 to 3 Mbps at maximum range. 802.16d (also called Fixed WiMAX) describes the backhaul implementation of the protocol. Improvements to this aspect have been published (802.16.1), but most WiMAX networks still implement a variation of 802.16d. 802.16 can operate in unlicensed bands, but its backhaul function is often deployed in more-reliable licensed bands, where interferences from other systems are better controlled.


Base Station
WiFi hotspots
WiMAX
router and switch
WiMAX network
Internet
Base Station
Mobile Station
Base Station
Risdentail Access

| Technology | Type and Range | Architectural Characteristics |
|---|---|---|
| Ethernet | Wired, 100 m max | Requires a cable per sensor/sensor group; adapted to static sensor position in a stable environment; range is limited; link is very reliable |
| Wi-Fi (2.4 GHz, 5 GHz) | Wireless, 100 m (multipoint) to a few kilometers (P2P) | Can connect multiple clients (typically fewer than 200) to a single AP; range is limited; adapted to cases where client power is not an issue (continuous power or client battery recharged easily); large bandwidth available, but interference from other systems likely; AP needs a cable |
| 802.11ah (HaloW, Wi-Fi in sub-1 GHz) | Wireless, 1.5 km (multipoint), 10 km (P2P) | Can connect a large number of clients (up to 6000 per AP); longer range than traditional Wi-Fi; power efficient; limited bandwidth; low adoption; and cost may be an issue |
| WiMAX (802.16) | Wireless, several kilometers (last mile), up to 50 km (backhaul) | Can connect a large number of clients; large bandwidth available in licensed spectrum (fee-based); reduced bandwidth in license-free spectrum (interferences from other systems likely); adoption varies on location |
| Cellular (for example, LTE) | Wireless, several kilometers | Can connect a large number of clients; large bandwidth available; licensed spectrum (interference-free; license-based) |

**Table** *Architectural Considerations for WiMAX and Cellular Technologies*

**C) Network Transport Sublayer:** The previous section describes a hierarchical communication architecture in which a series of smart objects report to a gateway that conveys the reported data over another medium and up to a central station. However, practical implementations are often flexible, with multiple transversal communication paths. For example, consider the case of IoT for the energy grid. Your house may have a meter that reports the energy consumption to a gateway over a wireless technology.

Other houses in your neighborhood (NAN) make the same report, likely to one or several gateways. The data to be transported is small and the interval is large (for example, four times per hour), resulting in a low-mobility, low throughput type of data structure, with transmission distances up to a mile. Several technologies (such as 802.11ah, 802.15.4, or LPWA) can be used for this collection segment. Other neighborhoods may also connect the same way, thus forming a FAN.

For example, the power utility's headend application server may be regional, and the gateway may relay to a wired or wireless backhaul technology. The structure appears to be hierarchical. Practically, however, this IoT system may achieve more than basic upstream reporting. If your power consumption becomes unusually high, the utility headend application server may need on-demand reporting from your meter at short intervals to follow the consumption trend. From a standard vertical push model, the transport structure changes and becomes bidirectional (downstream pull model instead of upstream push).

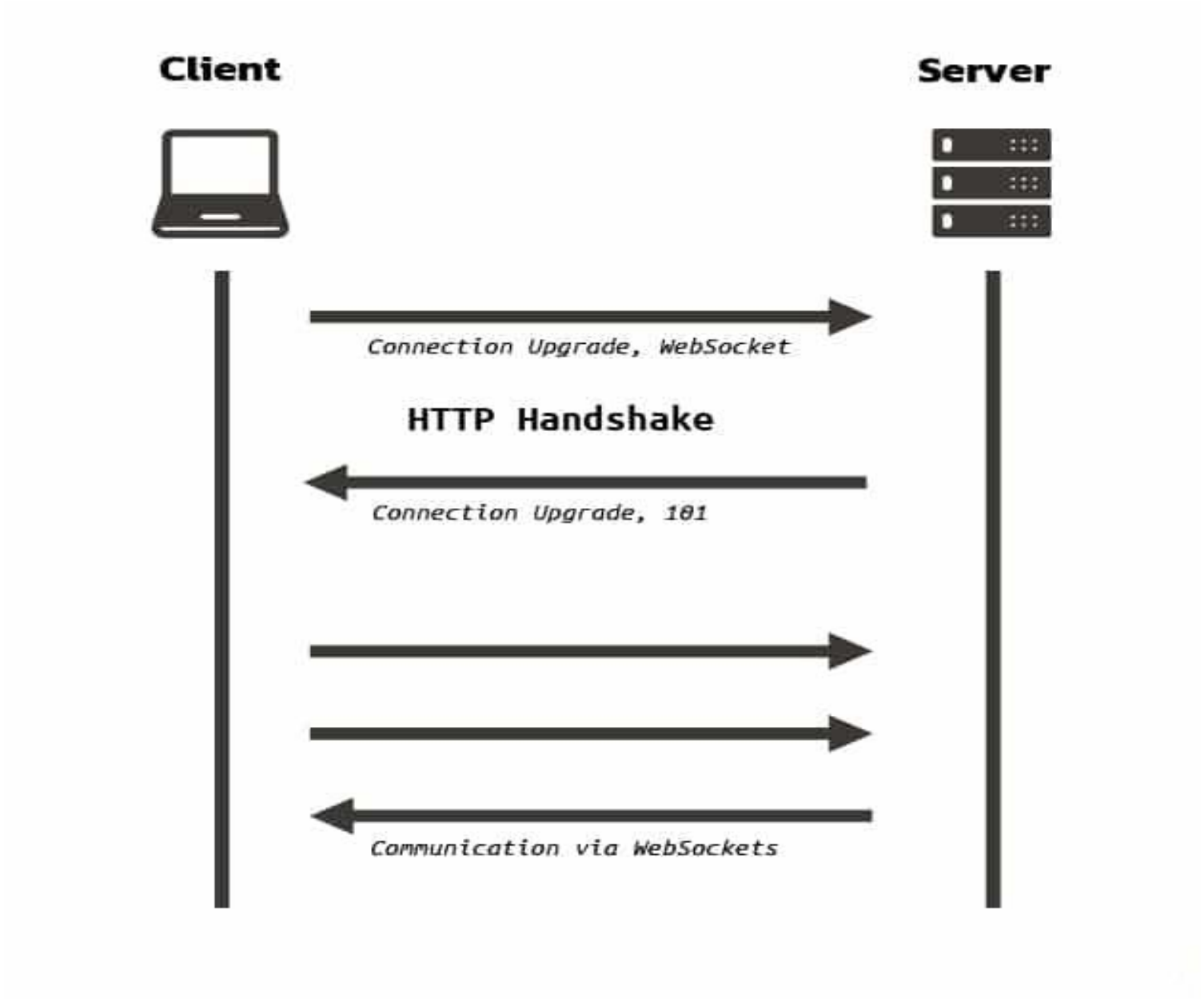
**Distribution automation (DA)** also allows your meter to communicate with neighboring meters or other devices in the electrical distribution grid. With such communication, consumption load balancing may be optimized. For example, your air conditioning pulses fresh air at regular intervals. With DA, your neighbor's AC starts pulsing when your system pauses; in this way, the air in both houses is kept fresh, but the energy consumed from the network is stable instead of spiking up and down with uncoordinated start and stop points. Here again, the transport model changes. From a vertical structure, you are now changing to a possible mesh structure with multiple peer-to-peer exchanges.

Similarly, your smart meter may communicate with your house appliances to evaluate their type and energy demand. With this scheme, your washing machine can be turned on in times of lower consumption from other systems, such as at night, while power to your home theater system will never be deprived, always turning on when you need it. Once the system learns your consumption pattern, charging of your electric car can start and stop at intervals to achieve the same overnight charge without creating spikes in energy demand. When these functions appear, the transport model changes again.

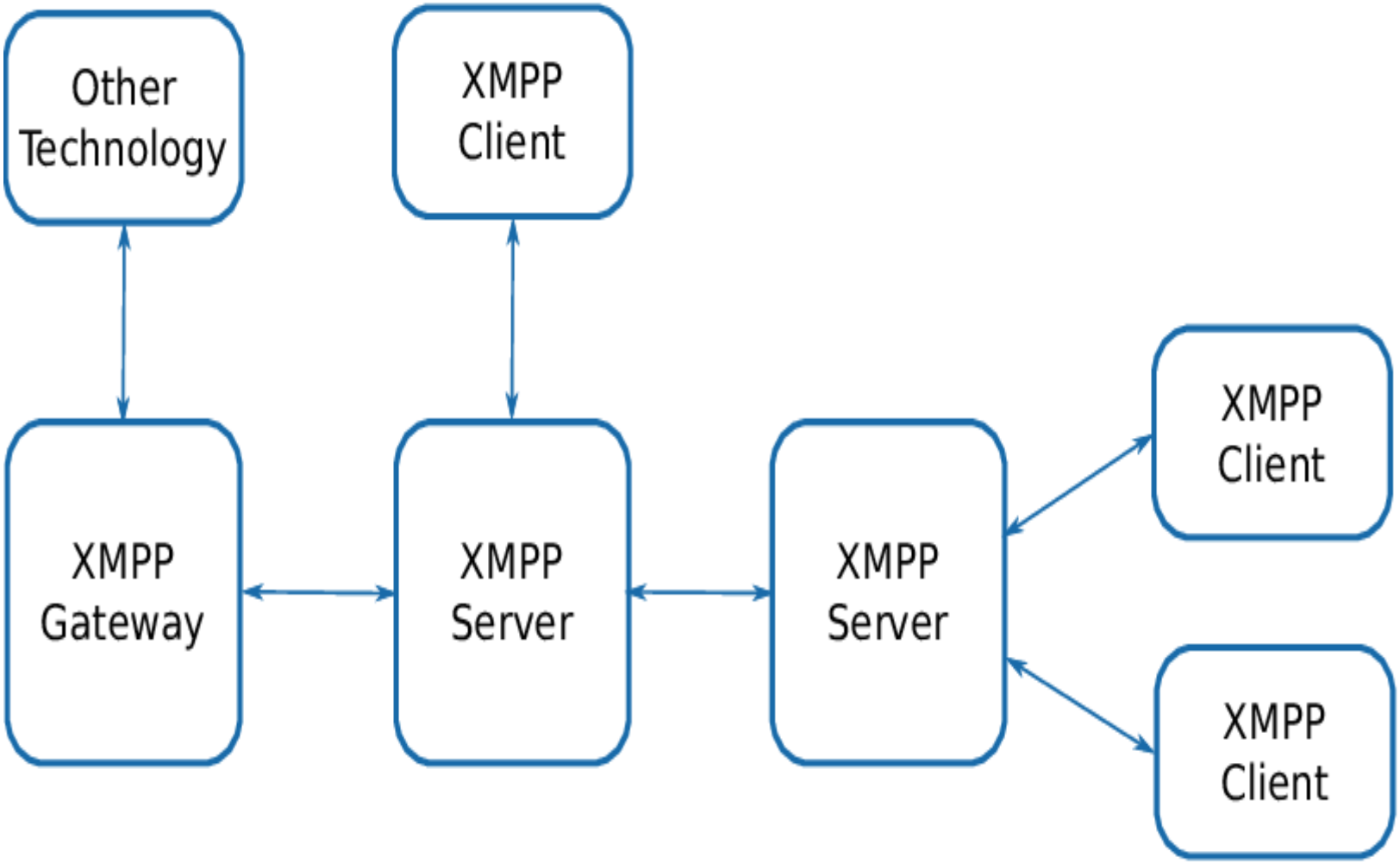
**D) IoT Network Management Sublayer:** IP, TCP, and UDP bring connectivity to IoT networks. Upper-layer protocols need to take care of data transmission between the smart objects and other systems. Multiple protocols have been leveraged or created to solve IoT data communication problems. Some networks rely on a push model (that is, a sensor reports at a regular interval or based on a local trigger), whereas others rely on a pull model (that is, an application queries the sensor over the network), and multiple hybrid approaches are also possible.

Following the IP logic, some IoT implementers have suggested **HTTP** for the data transfer phase. After all, HTTP has a client and server component. The sensor could use the client part to establish a connection to the IoT central application (the server), and then data can be exchanged. You can find HTTP in some IoT applications, but HTTP is something of a fat protocol and was not designed to operate in constrained environments with low memory, low power, low bandwidth, and a high rate of packet failure.

. Despite these limitations, other web-derived protocols have been suggested for the IoT space. One example is **Web Socket**. Web Socket is part of the HTML5 specification, and provides a simple bidirectional connection over a single connection. Some IoT solutions use Web Socket to manage the connection between the smart object and an external application. Web Socket is often combined with other protocols, such as MQTT (described shortly) to handle the IoT-specific part of the communication.


Client
Server
Connection Upgrade, WebSocket
HTTP Handshake
Connection Upgrade, 101
Communication via WebSockets

With the same logic of reusing well-known methods, **Extensible Messaging and Presence Protocol (XMPP)** was created. XMPP is based on instant messaging and presence. It allows the exchange of data between two or more systems and supports presence and contact list maintenance. It can also handle publish/subscribe, making it a good choice for distribution of information to multiple devices. A limitation of XMPP is its reliance on TCP, which may force subscribers to maintain open sessions to other systems and may be a limitation for memory-constrained objects.


Other Technology
XMPP Client
XMPP Gateway
XMPP Server
XMPP Server
XMPP Client
XMPP Client

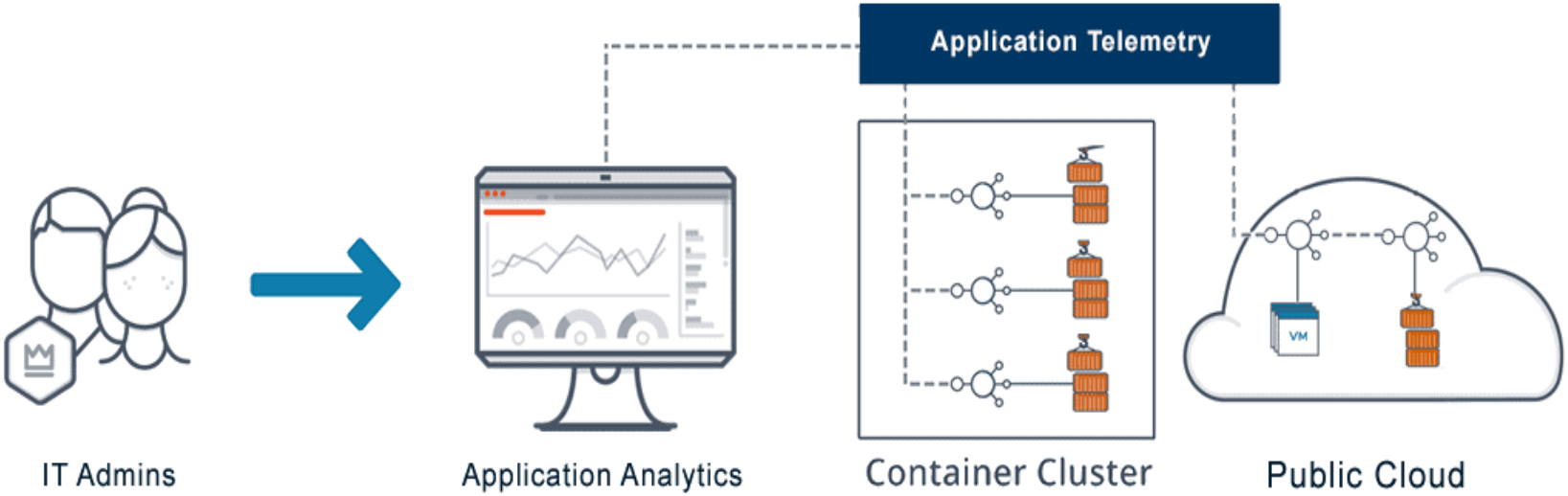
**Layer 3: Applications and Analytics Layer:**

Once connected to a network, your smart objects exchange information with other systems. As soon as your IoT network spans more than a few sensors, the power of the Internet of Things appears in the applications that make use of the information exchanged with the smart objects.

**Analytics Versus Control Applications**: Multiple applications can help increase the efficiency of an IoT network. Each application collects data and provides a range of functions based on analyzing the collected data. It can be difficult to compare the features offered.

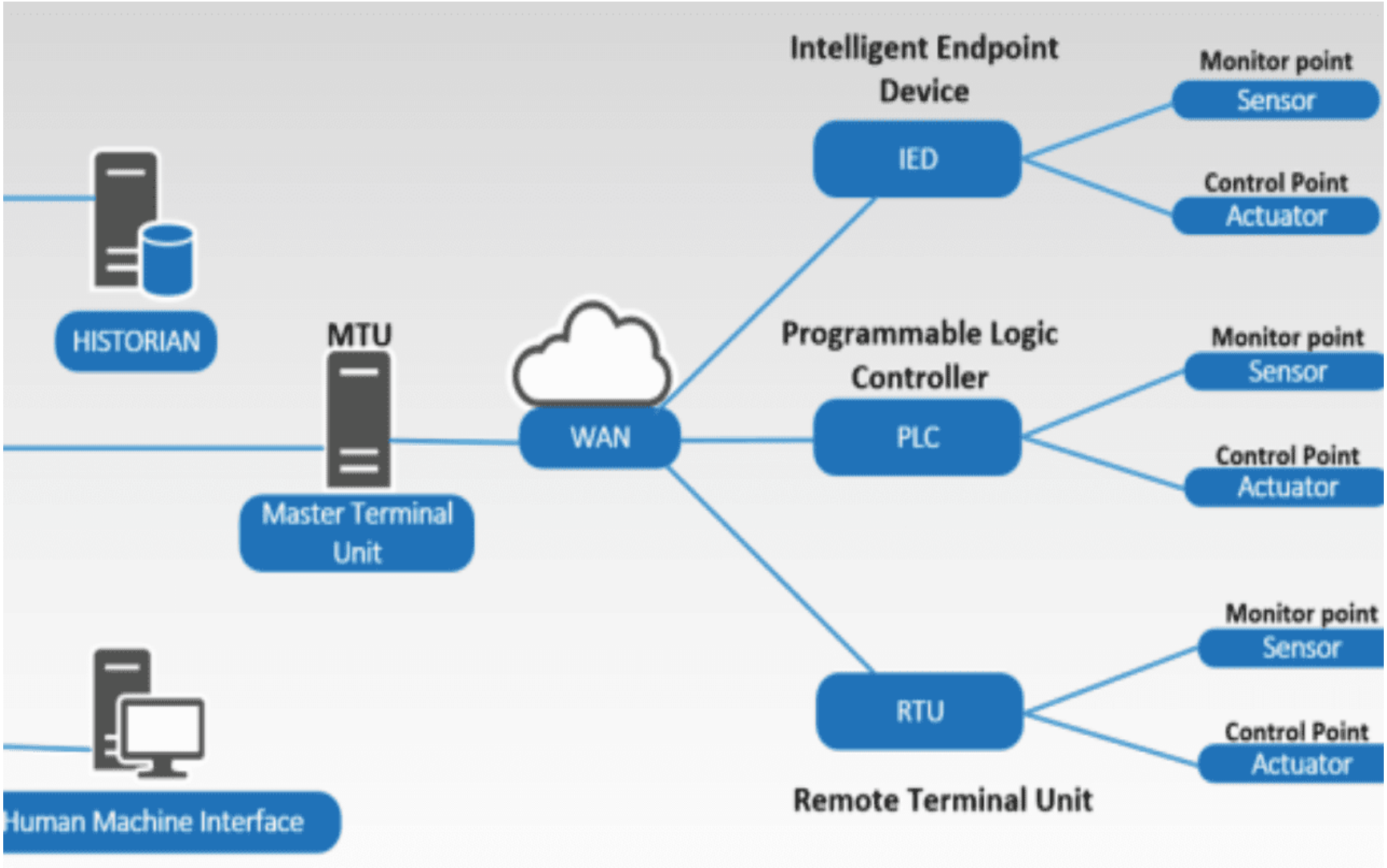
From an architectural standpoint, one basic classification can be as follows:

- **Analytics application**: This type of application collects data from multiple smart objects, processes the collected data, and displays information resulting from the data that was processed. The display can be about any aspect of the IoT network, from historical reports, statistics, or trends to individual system states. The important aspect is that the application processes the data to convey a view of the network that cannot be obtained from solely looking at the information displayed by a single smart object.


Application Telemetry
VM
IT Admins
Application Analytics
Container Cluster
Public Cloud

- **Control application:** This type of application controls the behavior of the smart object or the behavior of an object related to the smart object. For example, a pressure sensor may be connected to a pump. A control application increases the pump speed when the connected sensor detects a drop in pressure. Control applications are very useful for controlling complex aspects of an IoT network with a logic that cannot be programmed inside a single IoT object, either because the configured changes are too complex to fit into the local system or because the configured changes rely on parameters that include elements outside the IoT object.

An example of **control system** architecture is **SCADA**. SCADA was developed as a universal method to access remote systems and send instructions. One example where SCADA is widely used is in the control and monitoring of remote terminal units (RTUs) on the electrical distribution grid. Many advanced IoT applications include both analytics and control modules. In most cases, data is collected from the smart objects and processed in the analytics module

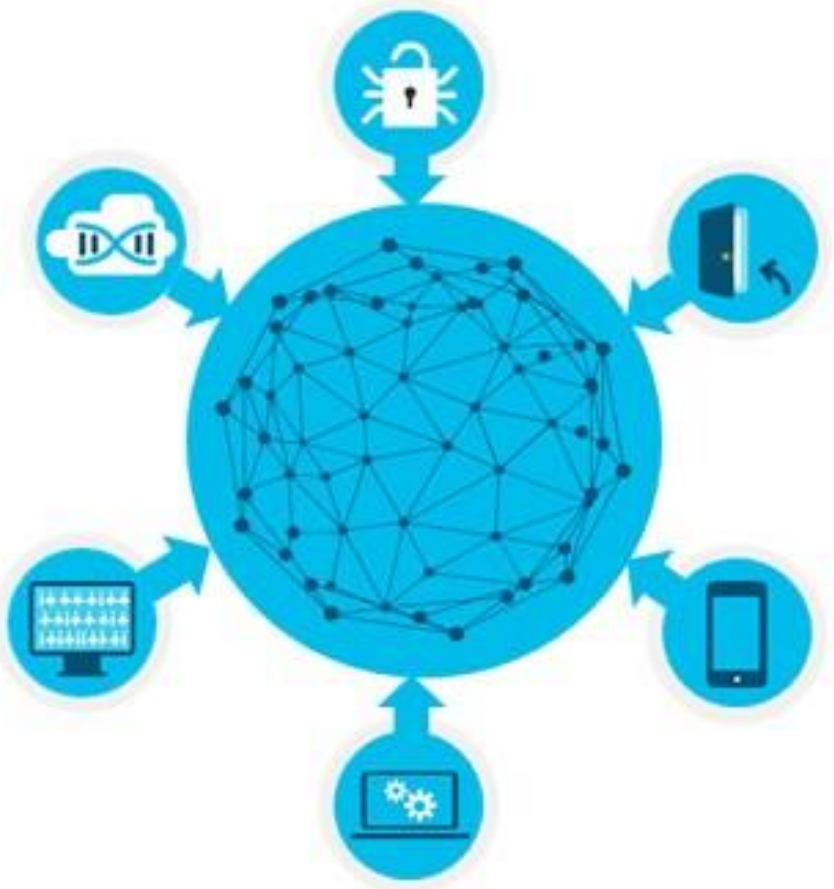

Intelligent Endpoint Device
IED
Monitor point
Sensor
Control Point
Actuator
HISTORIAN
MTU
WAN
Programmable Logic Controller
PLC
Monitor point
Sensor
Control Point
Actuator
Master Terminal Unit
Monitor point
Sensor
RTU
Control Point
Actuator
Human Machine Interface
Remote Terminal Unit

The result of this processing may be used to modify the behavior of smart objects or systems related to the smart objects. The control module is used to convey the instructions for behavioral changes. When evaluating an IoT data and analytics application, you need to determine the relative depth of the control part needed for your use case and match it against the type of analytics provided.

**Data Versus Network Analytics:** Analytics is a general term that describes processing information to make sense of collected data. In the world of IoT, a possible classification of the analytics function is as follows:

- Data analytics: This type of analytics processes the data collected by smart objects and combines it to provide an intelligent view related to the IoT system. At a very basic level, a dashboard can display an alarm when a weight sensor detects that a shelf is empty in a store.

In a more complex case, temperature, pressure, wind, humidity, and light levels collected from thousands of sensors may be combined and then processed to determine the likelihood of a storm and its possible path. In this case, data processing can be very complex and may combine multiple changing values over complex algorithms. Data analytics can also monitor the IoT system itself. For example, a machine or robot in a factory can report data about its own movements. This data can be used by an analytics application to report degradation in the movement speeds, which may be indicative of a need to service the robot before a part breaks.



- Network analytics: Most IoT systems are built around smart objects connected to the network. A loss or degradation in connectivity is likely to affect the efficiency of the system. Such a loss can have dramatic effects. For example, open mines use wireless networks to automatically pilot dump trucks. A lasting loss of connectivity may result in an accident or degradation of operations efficiency (automated dump trucks typically stop upon connectivity loss). On a more minor scale, loss of connectivity means that data stops being fed to your data analytics platform, and the system stops making intelligent analyses of the IoT system. A similar consequence is that the control module cannot modify local object behaviors anymore.

Most analytics applications employ both data and network analytics modules. When architecting an IoT system, you need to evaluate the need for each one. Network analytics is necessary for connected systems. However, the depth of analysis depends on your use cases. A basic connectivity view may be enough if the smart objects report occasional status, without expectation for immediate action based on this report.

Detailed analysis and trending about network performance are needed if the central application is expected to pilot in near-real-time connected systems. Data analytics is a wider space with a larger gray area (in terms of needs) than network analytics. Basic systems analytics can provide views of the system state and state trend analysis. More advanced systems can refine the type of data collected and display additional information about the system. The type of collected data and processing varies widely with the use case.

**Data Analytics Versus Business Benefits:** Data analytics is undoubtedly a field where the value of IoT is booming. Almost any object can be connected, and multiple types of sensors can be installed on a given object. Collecting and interpreting the data generated by these devices is where the value of IoT is realized. From an architectural standpoint, you can define static IoT networks where a clear list of elements to monitor and analytics to perform are determined.

**Smart Services:** The ability to use IoT to improve operations is often termed "smart services." This term is generic, and in many cases the term is used but its meaning is often stretched to include one form of service or another where an additional level of intelligence is provided. Fundamentally, smart services use IoT and aim for efficiency. For example, sensors can be installed on equipment to ensure ongoing conformance with regulations or safety requirements. This angle of efficiency can take multiple forms, from presence sensors in hazardous areas to weight threshold violation detectors on trucks.

Smart services can also be used to measure the efficiency of machines by detecting machine output, speed, or other forms of usage evaluation. Entire operations can be optimized with IoT. In hospitality, for example, presence and motion sensors can evaluate the number of guests in a lobby and redirect personnel accordingly. The same type of action can be taken in a store where a customer is detected as staying longer than the typical amount of time in front of a shelf. Personnel can be deployed to provide assistance. Movement of people and objects on factory floors can be analyzed to optimize the production flow.

Smart services can be integrated into an IoT system. For example, sensors can be integrated in a light bulb. A sensor can turn a light on or off based on the presence of a human in the room. An even smarter system can communicate with other systems in the house, learn the human movement pattern, and anticipate the presence of a human, turning on the light just before the person enters the room. An even smarter system can use smarter sensors that analyze multiple parameters to detect human mood and modify accordingly the light color to adapt to the learned preferences, or to convey either a more relaxing or a more dynamic environment.

Light bulbs are a simple example. By connecting to other systems in the house, efficiencies can be coordinated. For example, the house entry alarm system or the heating system can coordinate with the presence detector in a light bulb to adapt to detected changes. The alarm system can disable volumetric movement alarms in zones where a known person is detected. The heating system can adapt the temperature to human presence or detected personal preferences.

Similar efficiency can be extended to larger systems than a house. For example, smart grid applications can coordinate the energy consumption between houses to regulate the energy demand from the grid. We already mentioned that your washing machine may be turned on at night when the energy demand for heating and cooling is lower. Just as your air conditioning pulses can be coordinated with your neighbor's, your washing machine cycles can be coordinated with the appliances in your house and in the neighborhood to smooth the energy demand spikes on the grid.

Efficiency also applies to M2M communications. In mining environments, vehicles can communicate to regulate the flows between drills, draglines, bulldozers, and dump trucks, for example, making sure that a dump truck is always available when a bulldozer needs it. In smart cities, vehicles communicate. A traffic jam is detected and anticipated automatically by public transportation, and the system can temporarily reroute buses or regulate the number of buses servicing a specific line based on traffic and customer quantity, instantaneous or learned over trending.