# Communication/Networking Protocols – Part 2

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# IP and TCP

- Supporting IP layer consumes a lot of resources
- There are benefits in using TCP/IP
- Sensor data needs to be ultimately fed to public, private or hybrid cloud for analysis, control or monitoring
- Outside of WPAN, the world is TCP/IP-based
- So, a big role for IP in IoT!!

# IP Role in IoT

- **Ubiquity**: IP stacks are provided by nearly every OS and every medium – capable of running on various underlying systems
- **Longevity**: Has stood the test of time
- **Standards-based**: IETF maintains a set of open standards focused on Internet Protocol.
- **Scalability**: IPv6 could provide a unique IP address to anything and everything
- **Reliability**: Is reliable and considers *best-effort* delivery
- **Manageability:** Various tools exist to manage IP networks and devices on an IP network

# Tranport Layer

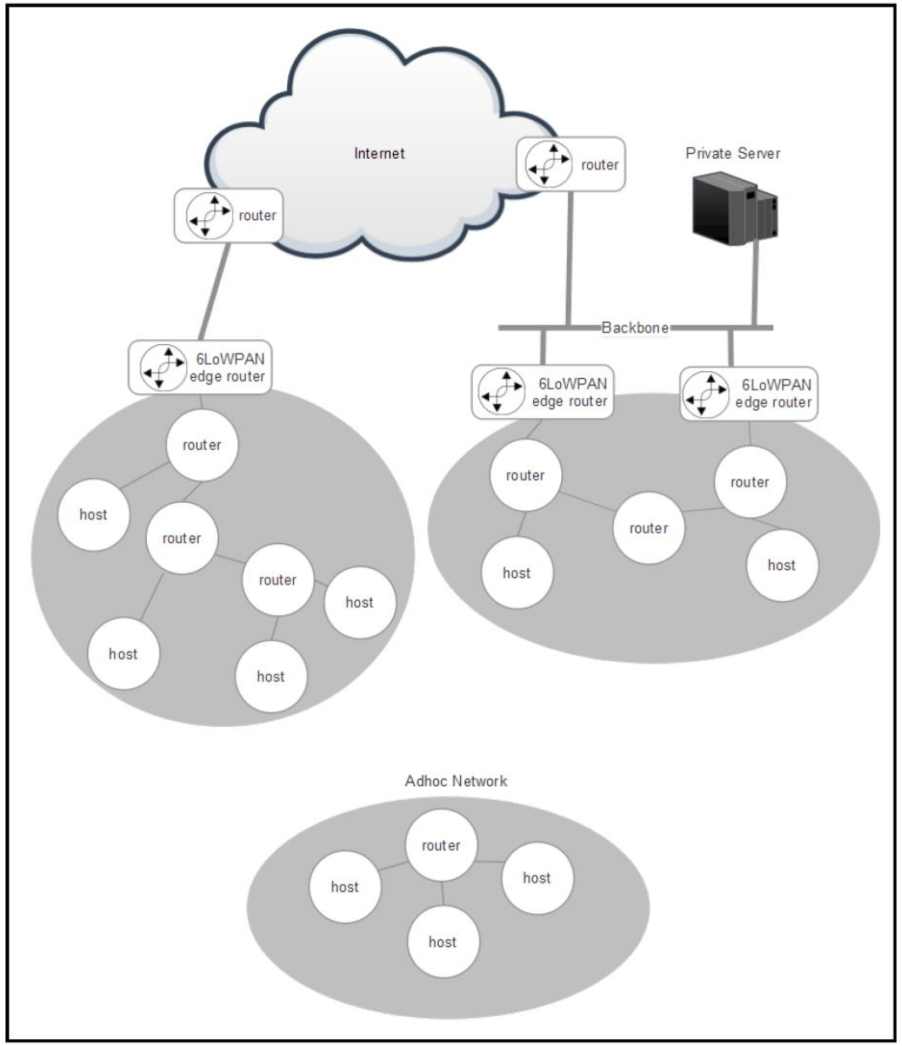
- TCP and Universal Datagram Protocol (UDP) are used in Transport Layer
- Responsible for end-to-end communication
- TCP is connection oriented whereas UDP is connection less
- TCP provides reliability using acknowledgement messages and retransmissions of lost messages
- TCP provides flow control using sliding windows and congestion avoidance algorithms
- UDP is much simpler to implement and is not reliable

# WPAN with IP – 6LoWPAN

- Bringing IP addressability to smallest and most resource-constrained devices
- 6LoWPAN was formed in 2005
- 6LoWPAN – Acronym that stands for IPV6 over low power WPANs

# 6LoWPAN Topology

- 6LoWPAN networks are mesh networks residing on the periphery of larger networks
- Flexible topologies allowing adhoc and disjointed networks without any binding to internet or other systems
- If connected to backbone, uses edge routers



# IEEE 802.11 and WLAN

- 802.11 specifies the Media Access Control (MAC) and physical layer (PHY) of a networking stack
- Wi-Fi is the definition of WLAN based on IEEE 802.11 standards maintained and governed by Wi-Fi alliance
- Success can be attributed to the layered stack approach of OSI model where the MAC and PHY layers can be simply replaced by the IEEE 802.11 layers

# IEEE 802.11 suite of protocols

- Original 802.11 goal was to provide a link layer protocol for wireless networking
- Evolved from 802.11 base specification to 802.11ac
- Since then, working group has focused on other areas
  - Low power/low bandwidth IoT interconnect (802.11ah)
  - Vehicle-to-Vehicle communication (802.11p)
- New variants designed for different areas of RF spectrum or to reduce latency and improve safety for vehicular emergencies

# Various IEEE 802.11 standards

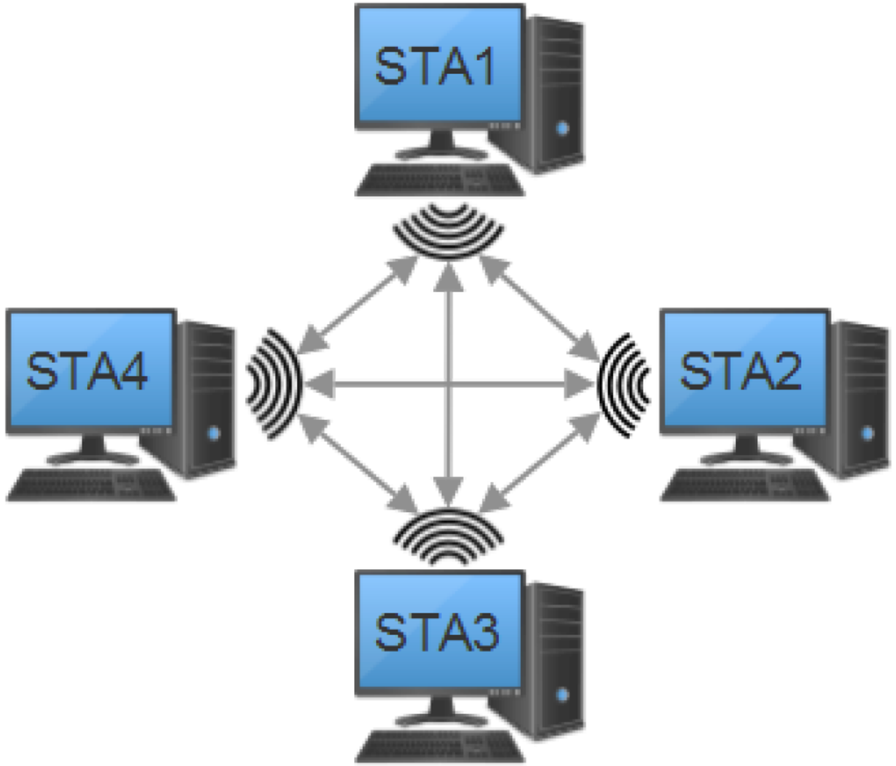
| IEEE 802.11 Protocol | Use Case | Release Date | Frequency (GHz) | Bandwidth (MHz) | Streaming Data Rate per Channel min-max (Mbps) | Allowable MIMO Streams | Modulation | Indoor Range (m) | Outdoor Range (m) | Typical Dissipated Power per Chip (mW) |
|---|---|---|---|---|---|---|---|---|---|---|
| 802.11 | First 802.11 design | Jun-97 | 2.4 | 22 | 1 to 2 | 1 | DSSS, FHSS | 20 | 20 | 50 |
| a | Release simulataneously with 802.11b<br>Less prone to intereferncе than 802.11b | Sep-99 | 5<br>3.7 | 20 | 6 to 54 | 1 | OFDM<br>(SISO) | 30 | 120<br>5000 | 50 |
| b | Release simulataneously with 802.11a<br>Significant speed increase over 802.11a at improved range | Sep-99 | 2.4 | 22 | 1 to 11 | 1 | DSSS (SISO) | 50 | 150 | 7 to 50 |
| g | Speed increase over 802.11b | Jun-03 | 2.4 | 20 | 6 to 54 | 1 | OFDM. DSSS (SISO) | 38 | 140 | 50 |
| n | Multiple antenna technology for improved speed, and range. | Oct-09 | 2.4 / 5 | 20<br>40 | 7.2 to 72.2<br>15 to 150 | 4 | OFDM (MIMO) | 70 | 250 | 40 |
| ac | Better performacne and coverage over 802.11n. Wider channel and improved modulation. Allows multiple users using MU-MIMO. Introduced beamforming. | Dec-13 | 5 | 20<br>40<br>80<br>160 | 7.2 to 96.3<br>15 to 200<br>32.5 to 433.3<br>65 to 866.7 | 8 | OFDM (MU_MIMO) | 35 | 35 | 40 |
| ah | "WiFi HaLow"<br>Designed for IoT and sensor networks. Very low power and wider range. | Dec-16 | 2.4 / 5 | 1 to 16 | 347 | 4 | OFDM | 1000 | 1000 | tbd but goal is low power |
| p | "Wireless Access in Vehicular Environments"<br>"Intelligent Transport Systems"<br>Dedicated Short Range Communication<br>Trnasport uses cases: toll collection, safety and collision emergencies, vehicular networking. | Jun-09 | 5.9 | 10 | 27 | 1 | OFDM | NA | 400 to 1000 | 40 |
| af | "white WiFi" or "Super WiFi"<br>Deploy unused spectrum in TV bands to provide last mile connectivity in India, Kenya, Singapoere, US and UK | Nov-13 | 0.470 to 0.710 | 6 to 8 | 568 | 4 | OFDM | NA | 6000-100,000 | tbd |
| ad | WiGig Alliance<br>60 GHz Wireless for HD video and projectors<br>Audio and video transport and cable replacement | Dec-12 | 60 | 2160 | 4260 | >10 | SC, OFDM (MU-MIMO) | 10 | 10 | tbd |
| ax | "High Efficiency Wireless (HEW)"<br>Next gen 802.11<br>4x increase in capacity over 802.11ac<br>Average increase of 4x speed per user over 802.11ac<br>Backwards compatible to 802.11a/b/g/n/ac<br>Dense deployment scenarios | 2019 | 2.4 / 5 | 20<br>40<br>80<br>160 | 450 to 10000 | 8 | OFDMA (MU-MIMO) | 35 | 35 | tbd |

# Supported Topologies by 802.11

- **Infrastructure:** A station (STA) refers to an 802.11 endpoint device that communicates with a central access point (AP).
- An AP can be a gateway to other networks (WAN), a router, or a true access point in a larger network
- Also known as Infrastructure Basic Set Service (BSS) – Star topology

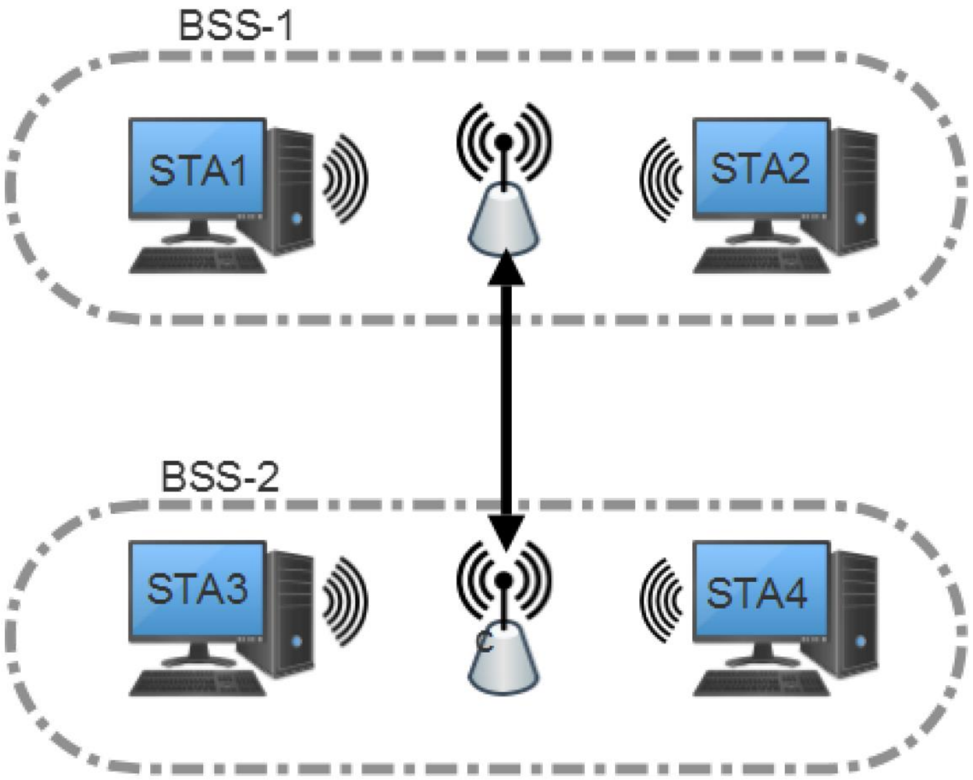
# Supported Topologies by 802.11

- **Ad hoc**: 802.11 nodes can form Independent Basic Set Service (IBSS)
- Each station communicates and manages the interface with other stations
- No access point – Peer to peer type of topology



# Supported Topologies by 802.11

- **Distribution system (DS)**: Combines two or more independent BSS networks through access point interconnects
- In total 802.11 protocol allows for up to 2007 STAs to be associated with a single access point



# IEEE 802.11 operation

- STA is a device equipped with wireless network interface controller
- An STA will always be listening for active communication in a specific channel
- First phase to connecting Wi-Fi is the scanning phase. Two types of scan mechanisms
  - Passive scanning:
    - ✓ After a channel is selected, device performing the scan will receive beacons and probe requests from nearby STAs
    - ✓ An access point may transmit a beacon, and the STA may join if it receives the transmitted beacon
  - Active scanning:
    - ✓ STA will attempt to locate an access point by instantiating probe requests
    - ✓ Uses more power but faster for joining
    - ✓ AP responds to probe request with a probe request response

# IEEE 802.11 operation

- An AP will typically broadcast a beacon at a fixed time interval called the Target Beacon Transmit Time (TBTT) – typically once in every 100 ms
- Beacons are always broadcast at lowest basic rates
- After a beacon is processed, next phase in Wi-Fi connectivity is **synchronization phase** – necessary to keep clients attuned to the AP
- Beacon packet contains information needed by the STA:
  - SSID: Service Set ID, 1-32 character network name
  - BSSID: Basic Service Set ID. Formed by combination of 24-bit Organization unique identifier and manufacturer's assigned 24-bit identifier for the radio chipset
  - Channel width: 20 MHz, 40 MHz and so on
  - Country: List of supported channels (country-specific)
  - Beacon interval (TBTT)
  - TIM/DTIM: Wake-up times and intervals to retrieve broadcast messages (for advanced power management)
  - Security services: WEP, WPA and WPA2 abilities
- If the STA finds an AP or another STA to connect, then it enters an **authentication phase**
- If authentication succeeds, next phase is **association** → Device sends an association request frame to the AP → AP will reply with an association response frame → If the STA is included in the network, AP will release an association ID to the client and add it to the list of connected clients

# Long-Range Communication (WAN)

- Sensors, actuators, cameras, vehicles, smart embedded devices, etc, will be in remotest of places and need to be connected to the internet or other systems → Need for WAN

# LoRaWAN Device Classes

Battery Lifetime

**A**

**Battery powered sensors**

- Most energy efficient
- Must be supported by all devices
- Downlink available only after sensor TX

**B**

**Battery powered actuators**

- Energy efficient w/ latency controlled downlink
- Slotted communication synchronized with a beacon

**C**

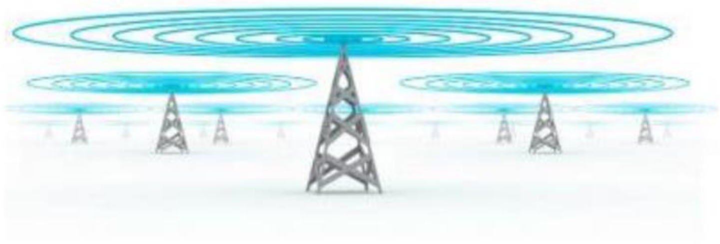
**Mains powered actuators**

- **Devices which can afford to listen continuously**
- **No latency for downlink communication**

**Downlink Network Communication Latency**

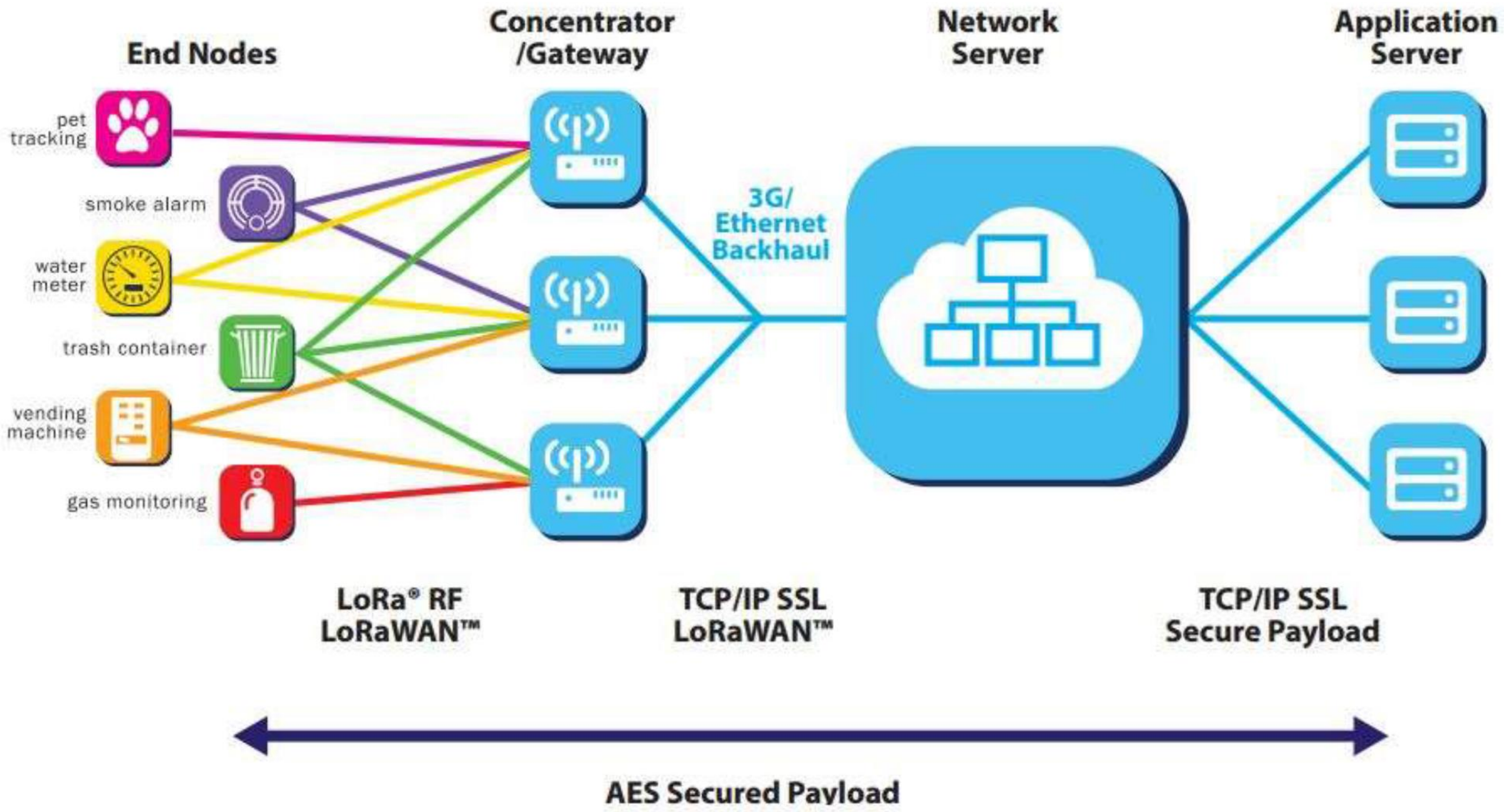
QUAENET

# LoRaWAN Network Features

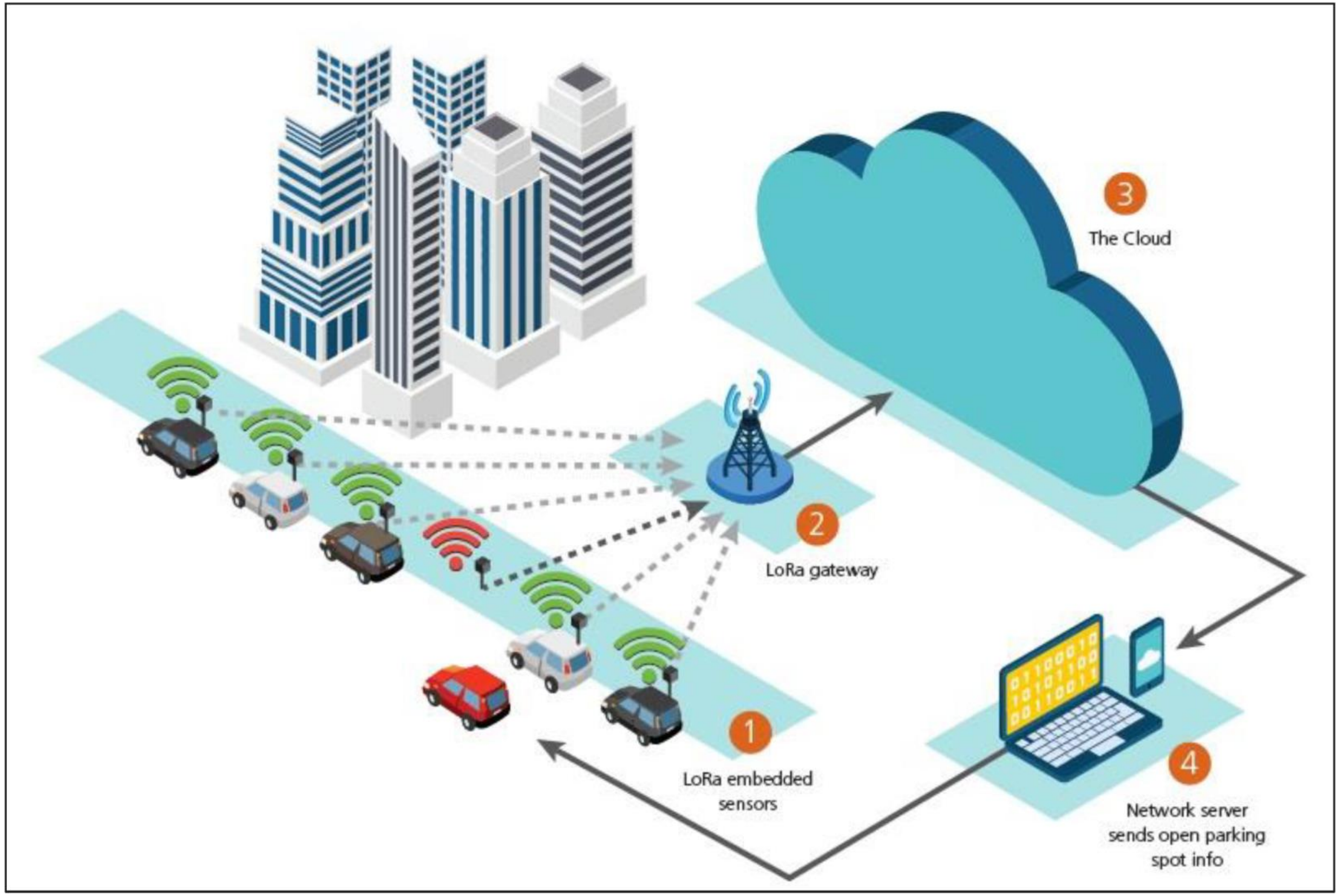


| Long Range | Max Lifetime | Multi Usage | Low Cost |
|---|---|---|---|
| ❑ Greater than cellular | ❑ Low power optimized | ❑ High capacity | ❑ Minimal infrastructure |
| ❑ Indoor coverage | ❑ 5-10yr lifetime | ❑ Multi-tenant | ❑ Low cost end-node |
| ❑ Star topology | ❑ >10x vs cellular M2M | ❑ Public network | ❑ Open SW |

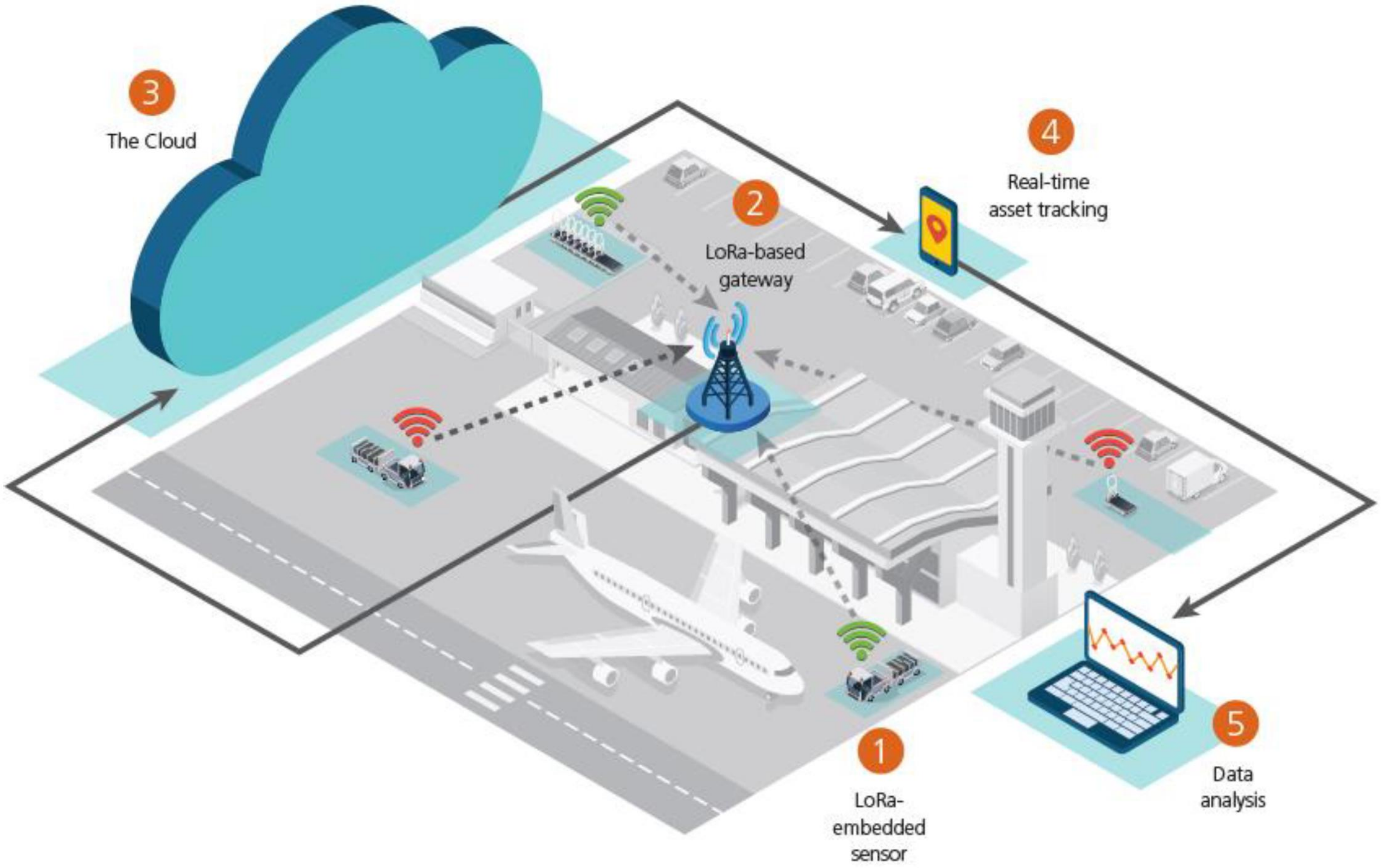
# Network Architecture



# LoRaWAN solutions – Parking Occupancy



# Asset Management



# Comparison of Long Range Communication Protocols

1. LoRa
2. SigFox
3. LTE-M

| Certification | Coverage | Payload | Data Rate (Max) | Frequency Range | Security | Power Consumption |
|---|---|---|---|---|---|---|
| Yes | 15 KM | 243 bytes | < 50 Kbps | 125 KHz | AES Encryption | 20dBm |
| Yes | 13 KM | 12 bytes | < 100 bps | 868/915 MHz | None | 13.5 dBm |
| Yes | 11 KM | 1000 bytes | < 1 Mbps | 20 MHz | AES Encryption | 23 dBm |

# Thank You