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Internet Of Things Report

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1 Q1 — Networked Sensor Device for tracking

We need a sensor device to track assets (vehicles and animals) in two wildlife parks:

- **Knuthenborg Safari Park**, Denmark
- **Mpala Research Center**, Kenya

The parks are large, and the devices must be able to track the location of the assets with a high degree of accuracy. The devices will be used to monitor the animals' movements and behavior, as well as to track the vehicles used for research and conservation efforts. The parks are located in different parts of the world, and the devices must be able to operate in different environments. The devices must be able to withstand harsh weather conditions, including extreme temperatures, rain, and dust. The devices must also be able to operate in remote areas with limited access to power and communication networks. tun

1.1 Functional requirements

- Location tracking (GPS)
- Measure acceleration (motion state)
- Measure particulate matter concentration
- Record data every hour (preferably real-time reporting)

1.2 Non-functional requirements

The devices must have an accuracy of at least 500 meters. Apart from that we need to consider environmental conditions, battery life, size, and cost.

Given that the devices will be used in wildlife parks, they must be able to withstand extreme temperatures, rain, and dust. Knuthenborg Safari Park is located in Denmark, where temperatures in worst case can drop to -20 degrees Celsius in winter and have hot humid summers. Mpala Research Center is located in Kenya, where temperatures can reach close to 40 degrees Celsius in summer.

Because the device needs to be able to track animals as many types of animals are present in the parks, the size of the device must be small enough to be attached to the animals without causing discomfort.

- Accuracy: $\geq$500 m or more
- Withstand extreme temperatures (e.g., -20 to 40 degrees Celsius)
- Withstand rain and dust (IP67 or better)
- Battery life: 0.5 years or more
- Track animals and vehicles
- Size has to be Small
- Cost: $100 or less

1.3 Device selection

1.4 Acceleration

For the acceleration we can would want to use a accelerometer. An example of a sensor could be the ADXL345, which measures at 3mm x 5mm x 1mm, has a range of up to +/-16g, and can operate in temperatures from -40 to +85 degrees Celsius. ADXL345 can measure the acceleration of the device in three dimensions so vertical movement of birds can be detected too if needed. It has a startup of 1.4ms, with a resolution of 13 bits, typically operates at 2.5V, and has a draw of 23μA in normal operation and 0.1μA in standby mode[1].

1.5 Particulate matter concentration

For the particulate matter concentration, we can use the Bosch BMV080 laser particle sensor. This compact sensor measures only 4.2 mm x 3 mm x 3.5 mm, making it ideal for our size constraints. A key advantage of the BMV080 is its fan-less. Unlike traditional particulate matter sensors that require fans to draw air through the sensing chamber, the BMV080 is able to measure particulate matter concentration without a fan. This is would be beneficial for our use case, as it reduces the risk of dust buildup on the sensor. Dust is especially problematic in wildlife environments like the parks that we want to deploy the devices in, as it can clog the fan and affect the sensor's performance. The sensor operates with a supply voltage of 1.8 to 3.3 V and has a quick start-up time of 1.2 seconds. It can function in temperatures ranging from -15°C to +65°C, which covers our operational requirements. The BMV080 is has a sleep current of less than 3μA and an average total current of less than 68mA at 0.97Hz output data rate. The datasheet conveniently also specifies that in duty cycling mode that we will use, then the sensor will use about 0.6mW each hour.

1.6 Location tracking

For the location tracking, we can use a GPS module. The GPS module is a small device that provides real-time location data by using satellite signals to determine the device's position. It offers accurate tracking even in remote areas like Mpala. An example of such a module is the u-blox MIA-M10, which measures just 4.5 mm x 4.5 mm x 1 mm. It supports our needs with a temperature range from -40°C to +85°C, has a cold start time of about 30 seconds, and has a positional accuracy of up to 2.5 meters. It has power consumption, drawing approximately 22mA at 3.3V during continuous tracking. However, with power supplied to the VBAT pin, it can retain satellite data and significantly reduce startup time to 1-10 seconds, using less energy per fix. In deep sleep mode with VBAT maintained, the module draws as little as 1μA.

1.6.1 Microcontroller and communication

Given that we want to send data over a long distance, we can use LoRaWAN for communication. An example of a microcontroller that supports LoRaWAN is the RAK3172 module based on the STM32WLE5 chip[6]. The module has an ARM Cortex-M4 core, which fits the host requirement for the Bosch BMV080 sensor. The RAK3172 measuring only 15 mm x 15.5 mm x 3.5 mm, making it suitable for our small-size requirements.

The module supports a temperature range from -40 °C to +85 °C, which is ideal for the extreme conditions in both wildlife parks. It operates with a supply voltage of 2.0 to 3.6 V, compatible with our other components. The module provides multiple I/O ports including UART, SPI, ADC, GPIO and most notably I2C which many of the sensors require.

For communication, the RAK3172 supports frequency ranges from 150 MHz to 960 MHz with a bandwidth from 7.8 kHz to 500 kHz, appropriate for long-distance, low-power transmission required in large wildlife parks. It supports multiple regional bands including EU433, CN470, RU864, IN865, EU868, AU915, US915, KR920, and AS923, making it deployable in both Denmark and Kenya with the appropriate regional settings.

A plus for the RAK3172 is the low power consumption of just 1.69 μA in sleep mode, which is critical for our battery life requirements. In operation i would assume it would draw around 10 mA for processing and communication tasks, which is manageable within our power budget. The module includes

256 KB flash memory with ECC (Error Correction Code) and 64 KB RAM, providing sufficient storage for our sensor data and communication protocols.

For our application, we would use this microcontroller to collect data from the sensors (GPS, accelerometer, and particulate matter sensor), process the data, and transmit it over LoRaWAN to a base station.

As we want to at least be sure we can send data 1km, we will set the LoRa transmission power to 14 dBm, which is the maximum allowed in the EU868 band. This will allow us to achieve a range of up to 10 km in open areas, which is more than sufficient for our needs in both wildlife parks.

1.6.2 Power supply

The device will be powered by a rechargeable lithium-ion battery. The battery should be able to provide power for at least 0.5 years of operation.

To know how much power we need, we can calculate the power consumption of the device. This will be a naive calculation, as we have not yet tested real-world power consumption, but it will give us an idea of the power requirements.

We know we need to send data every hour, and we can assume that the device will be in sleep mode most of the time to conserve power. We assume that the GPS module will be active for 10 seconds every hour to get a location fix, the accelerometer will be active for 1 second every hour to measure acceleration, and the particulate matter sensor will be active for 1 second every hour to measure particulate matter concentration. Assuming the following power consumption:

- GPS module: 22mA for 10 seconds every hour = $220\text{mA} \cdot \text{s}$
- Accelerometer: 23μA for 1 second every hour = $0.023\text{mA} \cdot \text{s}$
- Particulate matter sensor: 68mA for 1 second every hour = $68\text{mA} \cdot \text{s}$
- Microcontroller (active processing): 10mA for 13 seconds every hour = $130\text{mA} \cdot \text{s}$
- LoRaWAN transmission: 20mA for 1 second every hour = $20\text{mA} \cdot \text{s}$
- Sleep mode: 1.69μA for $(60 * 60) - 10 - 13 - 1 \simeq 3576$ seconds every hour = $6.044\text{mA} \cdot \text{s}$

Based on these values, we can calculate the total power consumption per hour. We need to use the formula for power consumption $P = I \cdot t$, where I is the current in milliamperes (mA) and t is the time in seconds (s). The total power consumption per hour will be the sum of the power consumption of each component. The power consumption will be given in milliampere-seconds ($\text{mA} \cdot \text{s}$) and then converted to milliampere-hours (mAh) by dividing by 3600 seconds per hour.

$$\begin{aligned}\text{Total per hour} &= 220\text{mA} \cdot \text{s} + 0.023\text{mA} \cdot \text{s} + 68\text{mA} \cdot \text{s} + 130\text{mA} \cdot \text{s} + 20\text{mA} \cdot \text{s} + 6.044\text{mA} \cdot \text{s} \\ &= 444.067\text{mA} \cdot \text{s} \approx 0.1234\text{mAh per hour}\end{aligned}$$

For a 6-month (0.5 year) deployment, we can calculate the total battery capacity required:

$$\begin{aligned}\text{Total capacity} &= 0.1234\text{mAh} \times 24\text{h} \times 365.25\text{days} \times 0.5\text{year} \\ &= 0.1234\text{mAh} \times 24\text{h} \times 182.625\text{days} \\ &= 0.1234\text{mAh} \times 4,383\text{h} \\ &= 540.86\text{mAh}\end{aligned}$$

To account for battery self-discharge, temperature effects, and capacity degradation over time, we should include a safety factor of at least 1.5:

$$\begin{aligned}\text{Required capacity} &= 540.86\text{mAh} \times 1.5 \\ &= 811.29\text{mAh} \approx 800\text{mAh}\end{aligned}$$

Therefore, a 600mAh lithium-ion battery would be sufficient for our application. However, to provide additional reliability and to account for potential harsh operating conditions in wildlife environments, we would recommend using a 1000mAh battery, which provides extra margin while still maintaining a reasonable size and weight.

For additional power supply, we can consider energy harvesting. A small solar panel rated at approximately 0.5W (measuring around 50mm $\times$ 50mm) would be sufficient to recharge the battery during daylight hours. With an average of just 1-2 hours of effective sunlight per day, this would provide enough additional energy to significantly extend the battery life beyond the required 6 months.

A potential issue would be that the device is not always exposed to sunlight, especially in the case of animals that might cover the cell from the sun with their body, fur or dirt. However, the generously-sized battery should compensate for periods without solar charging. The combination of a 1000mAh battery with solar recharging would likely enable the device to operate for well over a year in most deployment scenarios, and potentially indefinitely in locations with good sun exposure.

1.7 Device enclosure

To protect the device from environmental conditions, we can use an enclosure that is rated at least IP67. This means that the enclosure is dust-tight and can withstand immersion in water up to 1 meter for 30 minutes. The enclosure should also be able to withstand extreme temperatures, so we can use a material that can withstand temperatures from -40 to +85 degrees Celsius. We still need to allow air to get through the enclosure to allow the particulate matter sensor to do its work. A suitable material for the enclosure could be polycarbonate or ABS plastic, which are both durable and can withstand extreme temperatures. The enclosure should also be small enough to be attached to the animals without causing discomfort.

All the components we have selected would cover and area of about:

- ADXL345: 3mm x 5mm x 1mm
- BMV080: 4.2mm x 3mm x 3.5mm
- u-blox MIA-M10: 4.5mm x 4.5mm x 1mm
- RAK3172: 15mm x 15.5mm x 3.5mm
- Battery: 30mm x 20mm x 5mm (assuming a small lithium-ion battery)
- Solar panel: 50mm x 50mm x 2mm (assuming a small solar panel)

The total area of the components would be approximately:

$$\begin{aligned}
\text{Total area} &= (3 \times 5 \times 1) + (4.2 \times 3 \times 3.5) + (4.5 \times 4.5 \times 1) + (15 \times 15.5 \times 3.5) + (30 \times 20 \times 5) + \\
&= 15 + 44.1 + 20.25 + 817.5 + 3000 + 5000 \\
&= 8856.85 \text{ mm}^3
\end{aligned}$$

2 Question 2 — Wildlife Monitoring System Architecture

Building on the sensor device designed in Question 1, we now develop a system for tracking wildlife and vehicles in the two parks. The system will monitor animal movements and environmental conditions, providing valuable data for research and park management.

2.1 System Architecture

2.1.1 Architecture Overview

The system uses a layered IoT architecture to manage data from sensors and perform analytics. It includes four main layers:

- **Device Layer**: Sensor devices on animals and vehicles that collect data
- **Network Layer**: LoRaWAN infrastructure for long-range communication
- **Middleware Layer**: Central servers for data ingestion, processing, and storage
- **Application Layer**: User interfaces and analytics applications for data visualization and insights

Figure 1 illustrates the complete system architecture with data flow indicated by arrows.

2.1.2 Design Choices and Motivation

Device Layer The sensor devices developed in Question 1 form the device layer of our architecture. These devices include accelerometers (ADXL345), particulate matter sensors (BMV080), and GPS modules (u-blox MIA-M10), all controlled by the RAK3172 microcontroller.

Key design choices:

- **Edge Processing**: We implement lightweight processing on the devices themselves to reduce data transmission volume and save power.
- **Adaptive Sampling**: While the default sampling rate is hourly, the devices can adapt based on detected activity levels or environmental conditions.

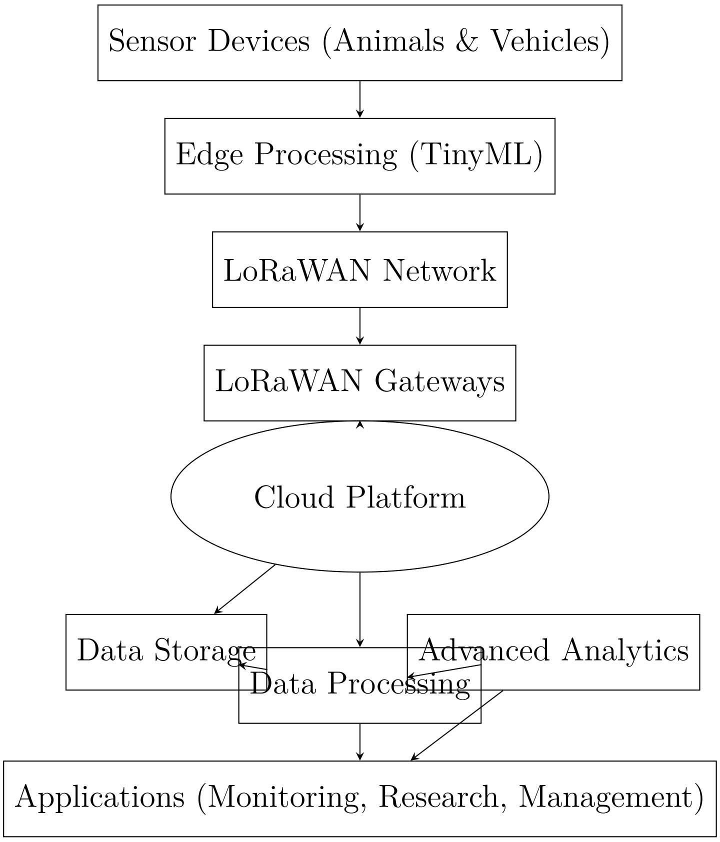

Figure 1: System Architecture for Wildlife Monitoring System

- **Energy Efficiency**: Solar-powered with backup batteries ensures long-term deployment in remote locations.

Network Layer LoRaWAN was selected as the communication technology due to its long-range capabilities (up to 10km in rural areas) and low power consumption. The network layer consists of:

- **LoRaWAN Gateways**: Strategically positioned throughout the wildlife parks, these gateways collect data from the sensor devices. For Knuthenborg Safari Park (1,600 acres), approximately 2-3 gateways would provide sufficient coverage. For the larger Mpala Research Center (48,000 acres), a more extensive network of 15-20 gateways would be optimal.
- **Backhaul Connectivity**: Gateways connect to the internet via cellular (4G/5G), satellite, or fixed wireless connections depending what is most feasible in the park's location. I am not sure i have enough

information about the parts to decide which connection type is best or feasible in each park.

Middleware Layer This layer handles data ingestion, processing, and storage:

- **Network Server**: Manages the LoRaWAN network protocols and communication.
- **Application Server**: Handles the application-specific data processing.
- **Data Storage**: A combination of time-series databases for raw sensor data and relational databases for things like processed results.
- **Message Broker**: Facilitates real-time data streaming between components using protocols like MQTT or Apache Kafka.

Application Layer The application layer provides user interfaces for researchers and park managers to access and analyze the data collected by the sensor devices. It includes:

- **Web Portal**: Provides access to real-time monitoring and historical data analysis.
- **API Services**: In case the parks want to share the data to other researchers or integrate with other systems.
- **Analytics Engine**: Provides advanced data processing, ML model training, and visualization capabilities.

Data Flow The data flow through the system follows these steps:

1. Sensor devices collect environmental and positioning data.
2. Edge processing filters and pre-processes data to extract relevant features.
3. Data is transmitted via LoRaWAN to nearby gateways.
4. Gateways forward data to the network and application servers.
5. Raw data is stored in time-series databases and processed data in relational databases.

6. Analytics pipelines process the data to extract insights and identify patterns.

7. Results are made available through web portals and APIs for researchers and park managers.

2.2 Analytics and Machine Learning

2.2.1 Role of Analytics

Analytics helps turn raw sensor data into useful information for wildlife research and park management.

Edge Analytics (Device Level) To maximize energy efficiency and reduce transmission bandwidth, we implement lightweight analytics directly on the sensor devices:

- **TinyML Implementation**: Using TensorFlow Lite for Microcontrollers on the Cortex-M4 core of the RAK3172 module.

- **Feature Extraction**: Computing statistical features (mean, variance, peaks) from raw accelerometer data to identify animal behaviors without transmitting full waveforms.

- **Anomaly Detection**: Simple algorithms to detect unusual movements or environmental conditions that warrant immediate reporting. Things like high particulate matter concentrations or sudden changes in movement patterns.

- **Adaptive Sampling**: Intelligent algorithms that adjust sampling frequency based on activity levels to conserve energy.

This approach significantly reduces power consumption by minimizing radio transmission, which is typically the most energy-intensive operation for IoT devices.

Cloud Analytics (System Level) In the cloud, we perform more analysis based on the aggregated data from all devices. This includes:

- **Behavioral Classification**: Machine learning models classify animal behaviors (resting, feeding, mating, migrating) based on movement patterns.

- **Health Monitoring**: Anomaly detection algorithms identify potential health issues in animals based on movement patterns and environmental exposure.
- **Environmental Monitoring**: Analysis of particulate matter data to track air quality across different park regions and correlate with animal behavior.
- **Spatial Analysis**: Tracking movement patterns over time to identify seasonal migration patterns, territory boundaries, and habitat utilization.
- **Forecasting**: Predictive models for animal movement patterns, population dynamics, and environmental conditions. This could include data from external sources like weather data, predicting how weather changes might affect animal behavior or habitat usage.

2.2.2 Decisions and Ratings of Interest

The analytics system generates several key insights that aid in research and park management:

Animal Health and Safety

- **Activity Level Assessment**: Extended periods of abnormally low activity could indicate injury or illness.
- **Stress Detection**: Periods of higher acceleration might indicate stress or flight responses.
- **Environmental Exposure Rating**: Prolonged exposure to high particulate matter concentrations may correlate with respiratory distress, especially in sensitive species.

Environmental Management

- **Air Quality Mapping**: Creating detailed maps of particulate matter concentrations to identify pollution hotspots.
- **Correlation Analysis**: Linking particulate matter levels with wind patterns, human activity, and animal distribution.
- **Impact Assessment**: Measuring how vehicle traffic patterns correlate with local air quality and animal behavior changes.

Research Insights

- **Interaction Networks**: Identifying social structures and inter-species interactions through proximity analysis.
- **Habitat Utilization**: Quantifying how different species use available habitat based on movement data.

2.2.3 Data Augmentation with External Sources

The value of our sensor data can be significantly enhanced by integration with external data sources:

Weather Data

- **Source**: Local weather stations, satellite data, or weather APIs
- **Enhanced Analytics**: Correlating animal behavior with temperature, precipitation, barometric pressure, and wind patterns
- **Example Insight**: How extreme weather events influence migration patterns or habitat usage

Satellite Imagery

- **Source**: Sentinel, Landsat, or commercial satellite providers
- **Enhanced Analytics**: Correlating animal movements with vegetation indices, water availability, and land cover changes
- **Example Insight**: How seasonal vegetation changes influence foraging patterns

Human Activity Data

- **Source**: Tourism records, road traffic counters, park management systems
- **Enhanced Analytics**: Assessing the impact of tourist presence and vehicle movements on wildlife behavior
- **Example Insight**: Optimal visitor management strategies that minimize wildlife disturbance

Historical Research Data

- **Source**: Previous studies, published research, long-term monitoring programs
- **Enhanced Analytics**: Comparing current behavioral patterns with historical baselines
- **Example Insight**: Long-term trends in habitat utilization and adaptation to environmental changes

2.3 System Scalability

2.3.1 Scaling Dimensions

Our system must scale across several dimensions:

Device Scaling As the number of tracked animals and vehicles increases, the system must accommodate more sensor devices:

- **LoRaWAN Capacity**: Each gateway can handle thousands of devices, with network capacity managed through adaptive data rates and transmission scheduling.
- **Device Management**: Automated provisioning, configuration, and firmware update systems ensure efficient management of large device fleets.
- **Battery Replacement Strategy**: Tracking battery status and scheduling maintenance operations to minimize disruption to animals and research.

Geographic Scaling Extending monitoring to new areas or parks:

- **Modular Gateway Deployment**: Standardized gateway configurations allow rapid deployment in new areas.
- **Regional Servers**: For global scaling, regional processing centers can be established to minimize latency and comply with data sovereignty requirements.
- **Adaptive Coverage**: Analyzing signal strength maps to optimize gateway placement for maximum coverage.

User Scaling Supporting increased numbers of researchers, park managers, and other stakeholders:

- **Role-Based Access Control**: Granular permissions ensure users can access only relevant data.
- **Multi-Tenant Architecture**: Logical separation of data and computing resources per organization or research group.
- **API Rate Limiting**: Ensuring fair resource utilization across increasing user numbers.

Data Volume Scaling Managing growing historical datasets:

- **Data Tiering**: Automatic migration of older data to lower-cost storage.
- **Aggregation Strategies**: Pre-computing aggregates at different time scales to maintain query performance.
- **Distributed Storage**: Sharding and partitioning strategies for the time-series database.

2.3.2 Potential Bottlenecks and Solutions

Network Bandwidth

- **Bottleneck**: Limited backhaul connectivity from remote gateway locations
- **Solution**:
  - Implement store-and-forward mechanisms at gateways during connectivity interruptions
  - Prioritize traffic based on urgency and importance
  - Deploy edge computing capabilities at gateway locations to reduce backhaul requirements

Battery Life

- **Bottleneck**: Increased sensing or transmission frequency could deplete batteries
- **Solution**:
  - Implement dynamic power management based on activity levels
  - Further optimize solar harvesting with better panel positioning
  - Develop AI models that extract more information from fewer sensor readings

Data Processing

- **Bottleneck**: Complex analytics becoming compute-intensive as data volumes grow
- **Solution**:
  - Implement auto-scaling cloud resources based on processing demand
  - Develop incremental processing algorithms that update existing results rather than reprocessing all data
  - Use distributed processing frameworks (e.g., Apache Spark) for large-scale batch analytics

Maintenance Logistics

- **Bottleneck**: Physical access to devices on wild animals presents unique challenges
- **Solution**:
  - Design collars with automatic release mechanisms triggered remotely when battery replacement is needed
  - Implement predictive maintenance to schedule interventions during routine research activities
  - Maximize component lifecycle through aggressive power management

2.4 Conclusion

The proposed monitoring system architecture provides a comprehensive solution for wildlife tracking and environmental monitoring in the two safari parks. By combining edge processing with cloud analytics, the system balances power efficiency with sophisticated analytical capabilities. The scalable design ensures the system can grow to accommodate increased numbers of tracked animals, expanded geographic coverage, and more complex analytics over time. Integration with external data sources further enhances the system's value for research and park management purposes.

3 Question 3

4 Sensor precision VS sensor accuracy

Sensor **precision** refers to the degree to which repeated measurements under unchanged conditions show the same results. In other words, it indicates how consistent the measurements are. For example, in dart if all darts land in the same area, even if that area is far from the bullseye, the sensor is precise. Precision does not imply correctness; it only indicates that the measurements are repeatable and consistent.

Sensor **accuracy**, on the other hand, refers to how close a measured value is to the true value. A sensor can be precise but not accurate if it consistently gives the same incorrect measurement. Conversely, a sensor can be accurate but not precise if it gives varying measurements that are close to the true value. For example, if all darts land close to the bullseye, the sensor is accurate. Accuracy indicates correctness and reliability of the measurements.

4.1 MQTT and it's role in IoT

MQTT (Message Queuing Telemetry Transport) is a lightweight messaging protocol designed for low-bandwidth, high-latency, on unreliable networks[5]. It is a publish-subscribe messaging protocol that theoretically can run over any transport protocol that ensures ordered, lossless, bi-directional connections. However, it is most commonly used over TCP/IP.

MQTT plays a crucial role in IoT by providing efficient communication for resource-constrained devices. With MQTT devices can send data to a central server (broker) without needing to establish a two way connection or wait for a response. This is particularly beneficial for battery-powered devices, as they can send their data and then enter a low-power sleep mode, conserving energy while still maintaining connectivity.

Its lightweight design minimizes bandwidth usage and power consumption, making it ideal for battery-operated devices. The protocol's small packet size and minimal overhead allow for efficient operation on bandwidth-constrained networks. MQTT's quality of service levels ensure reliable message delivery according to application needs, while its last will feature helps detect unexpected device disconnections.

MQTT is particularly valuable in IoT applications because devices can publish their data to a broker without maintaining persistent connections. This publish-subscribe model enables devices to send data and then enter low-power sleep modes, significantly extending battery life while maintaining effective communication.

4.2 All relevant layers of Wi-Fi, Bluetooth, LoRa and LoRaWan and their use in IoT

WiFi and Bluetooth are relevant for the OSI model layers 1 (physical) and 2 (data link), while LoRa and LoRaWAN are relevant for the OSI model layers 1, 2, and 3 (network).

WiFi and Bluetooth physical layer operate in the 2.4 GHz radio frequency band. The data link layer is responsible for the MAC protocol, which is used to control access to the transmission channel. Bluetooth uses a frequency-hopping spread spectrum (FHSS) which also belongs to the data link layer[3, 2]. These technologies are typically used for short-range communication, such as connecting devices within a home or office network. The technologies are designed for high-bandwidth applications, such as video streaming and file transfer. WiFi has a range of up to 100 meters, while Bluetooth has a range of up to 10 meters. For IoT applications, WiFi and Bluetooth are often used for local communication with cameras, sensors, and other devices that require high data rates and low latency.

LoRa is a physical layer technology that uses Chirp Spread Spectrum (CSS) modulation to achieve long-range, low-power communication. It operates in the sub-GHz frequency bands (e.g., 433 MHz, 868 MHz, 915 MHz). LoRaWAN is built on top of LoRa and adds network layer functionality. It defines the communication protocol and system architecture for the network, handling critical functions such as device authentication, data encryption, adaptive data rates, and end-to-end security[4]. While LoRa enables the long-distance link between devices, LoRaWAN provides the networking framework that allows multiple devices to communicate with gateways connected to the internet. With LoRaWAN, devices can send small amounts of data over long distances (up to 15 km in rural areas) while consuming very little power, making it ideal for remote battery-operated IoT devices.

4.3 Security features of the LoRaWAN protocol

LoRaWAN has AES-128 encryption, which is a symmetric encryption algorithm that uses a 128-bit key to encrypt and decrypt data. This ensures that only authorized devices can access the data transmitted over the network/in the air.

LoRaWAN also has a unique device identifier (DevEUI) and application identifier (AppEUI) for each device, which helps to identify and authenticate devices on the network. The DevEUI is a globally unique identifier assigned to each device, while the AppEUI is used to identify the application that the device is associated with.

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