Assignment 1.1: Infrastructure Diagram and Reference Document

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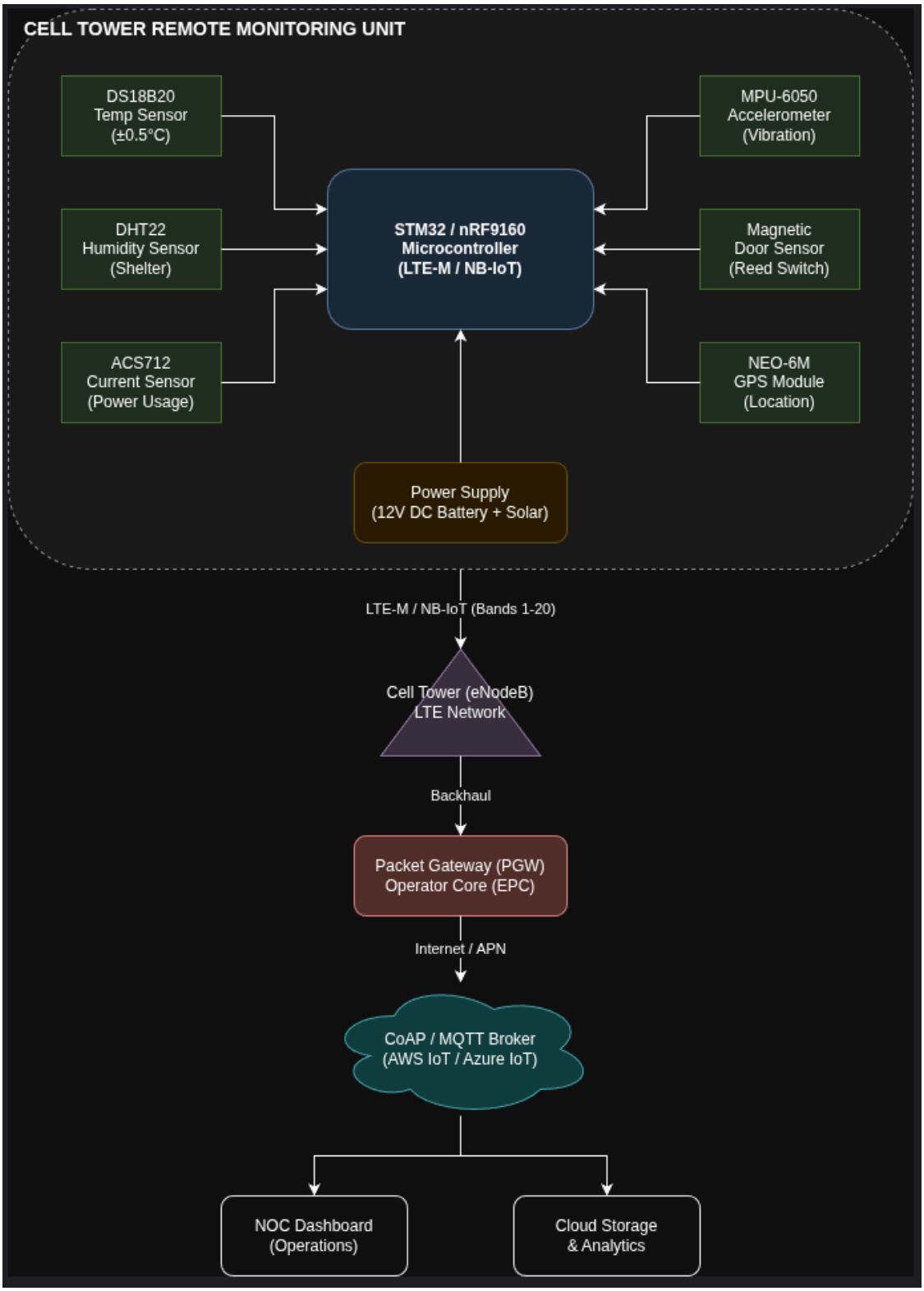
Device: Cell Tower Remote Monitoring System

Deliverable 1: Infrastructure Diagram

The following diagram illustrates the **Cell Tower Remote Monitoring System**. It identifies the physical placement of sensors, the connectivity type, and the messaging protocols used for communication.

Note: Reference document key information was collected using Gemini.

1.1 Physical Device Layout & Sensor Placement



1.2 Connectivity and Protocol Summary

- **Connectivity Type:** LTE Cat-M1 (LTE-M) and LTE Cat-NB1 (NB-IoT). These provide wide-area coverage with high penetration for industrial telecommunications environments.
- **Messaging Protocol: CoAP (Constrained Application Protocol)** over UDP. This is chosen for its low overhead and efficiency on metered cellular IoT data plans.

Deliverable 2: Reference Document

This section provides the technical details for each component identified in the infrastructure diagram, including functions, limitations, and environmental considerations.

1. DS18B20 Digital Temperature Sensor

- **Function:** Provides high-precision temperature monitoring for sensitive radio equipment and battery banks to prevent thermal runaway.
- **Technical Specifications:** Range: -55°C to +125°C; Accuracy: ±0.5°C; 12-bit resolution.
- **Limitations:** Slow conversion time (750ms); 1-Wire bus length is limited to ~100m without amplification.
- **Environmental Considerations:** Requires shielded cabling when placed near high-power RF transmitters to avoid signal interference.

2. DHT22 Temperature and Humidity Sensor

- **Function:** Monitors ambient humidity inside the shelter to prevent condensation and corrosion of electronic backplane components.
- **Technical Specifications:** Humidity Range: 0-100% RH; Sampling Rate: 0.5 Hz (every 2 seconds).
- **Limitations:** Performance degrades in high-humidity (>90%) environments; sampling rate is too slow for rapid environmental changes.
- **Environmental Considerations:** Susceptible to contamination from dust and salt spray in coastal environments; requires protective housing.

3. ACS712 Current Sensor

- **Function:** Measures AC/DC current consumption to detect power anomalies, equipment failure, or power theft at the site.
- **Technical Specifications:** Hall-effect based; Bandwidth: 80 kHz; 5 microseconds response time.
- **Limitations:** Accuracy varies (±5%) based on temperature; susceptible to nearby magnetic fields.
- **Environmental Considerations:** Accuracy degrades outside 0°C to 70°C; mounting orientation relative to Earth's magnetic field can cause offset.

4. MPU-6050 Accelerometer and Gyroscope

- **Function:** Detects structural vibration and tower sway caused by wind, seismic activity, or loose mounting hardware.
- **Technical Specifications:** 6-axis motion tracking; I2C interface; ±2g to ±16g selectable range.
- **Limitations:** Gyroscope suffers from drift over time; requires significant local digital filtering for clean vibration data.
- **Environmental Considerations:** Must be rigidly mounted to the tower structure; temperature extremes can affect sensitivity and offset.

5. Magnetic Door Sensor (Reed Switch)

- **Function:** Provides physical security alerts by detecting whenever the cabinet or shelter doors are opened.
- **Technical Specifications:** Normally Open (NO) switch; operates via 10-20mm magnetic gap.
- **Limitations:** Binary state only (open/closed); can be defeated by external magnets (lack of anti-tamper).
- **Environmental Considerations:** Magnets can lose strength in extreme heat; mechanical vibration can cause "contact bounce" or false triggers.

6. NEO-6M GPS Module

- **Function:** Provides precise geolocation to verify asset location and detect unauthorized relocation or theft of equipment.
- **Technical Specifications:** 50-channel engine; 2.5m position accuracy; -161 dBm sensitivity.
- **Limitations:** High power consumption (45mA); poor performance indoors or under heavy tree canopy; 27-second cold start time.
- **Environmental Considerations:** Requires a clear sky view; antenna needs surge/lightning protection for outdoor installation.

7. nRF9160 Microcontroller (MCU) & Modem

- **Function:** The "brain" of the system; aggregates sensor data, manages power states, and handles cellular transmission via LTE-M/NB-IoT.
- **Technical Specifications:** ARM Cortex-M33 (64MHz); 1MB Flash; Integrated LTE-M/NB-IoT modem; ARM TrustZone security.
- **Limitations:** No 5G support; memory constraints limit heavy local data buffering; performance depends on local carrier signal quality.
- **Environmental Considerations:** Industrial-grade operating range (-40°C to 85°C); requires robust power management to handle 500mA transmission spikes.

8. LTE-M / NB-IoT Connectivity

- **Function:** Wireless wide-area transport for sending data from the tower site to the central cloud platform.

- **Limitations:** Lower data rates (max 1Mbps) unsuitable for video; latency can be high (up to 10 seconds on NB-IoT).
- **Technical Specs:** Operates on licensed cellular bands (B1, B2, B4, B12, etc.); supports Power Saving Mode (PSM) for long battery life.

9. CoAP Messaging Protocol

- **Function:** Lightweight communication protocol used to package sensor data for transmission over the cellular network.
- **Limitations:** UDP-based transport means reliability (acknowledgments) must be managed at the application layer.
- **Technical Specs:** RESTful architecture (GET/POST); 4-byte header minimum; uses DTLS for security.