AI-driven energy-aware dynamic QoS management for 6G IoT

A proof of concept of the 6G-VERSUS triplet in Port environmental monitoring

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Introduction

Continuous IoT-based sensing in **B5G/6G networks** requires reliable connectivity while minimizing device energy consumption [1, 2]. At the same time, 6G IoT is evolving towards **programmable and application-aware networks**, where **NR RedCap** supports lower-power IoT devices, and **NEF**, via **CAPIF as unified gateway**, enable secure exposure of network capabilities through standardized network APIs. Additionally, industry initiatives such as **CAMARA** further accelerate this shift through developer-facing APIs such as **Quality on Demand (QoD)** [4].

However, QoS adaptation remains mostly **network-centric** and rarely considers the **real-time or predicted energy state** of IoT devices.

Objective: Design and validate an **energy-aware QoS management architecture** where device energy information and AI-based recommendations trigger network and device reconfiguration through standardized network APIs.

6G Application Triplet

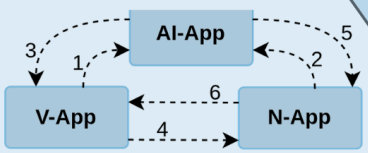

Figure 1: 6G-VERSUS Application triplet.

Following the **6G-VERSUS architecture** [3], the proposed system adopts a 6G Application Triplet composed of a V-App, an AI-App, and an N-App, as illustrated in Figure 1.

- **Vertical App (V-App):** Implements vertical logic and user-facing interfaces with real-time data visualization.
- **AI-assisted App (AI-App):** Applies ML to data from the V-App and N-App (1, 2) and returns insights to the V-App (3) for context-aware operation.
- **Network App (N-App):** Translates V-App service requirements (4) and AI-App intelligence outputs (5) into native 5G API requests, while relaying network information back to the V-App (6).

Use case

The target use case is port environmental monitoring using smart buoys operating as **NR RedCap** devices with **energy-harvesting capabilities**. The solution enables long-term autonomous sensing in areas affected by port operations while reducing maintenance and battery replacement needs.

Figure 2: Use case.

PoC Architecture

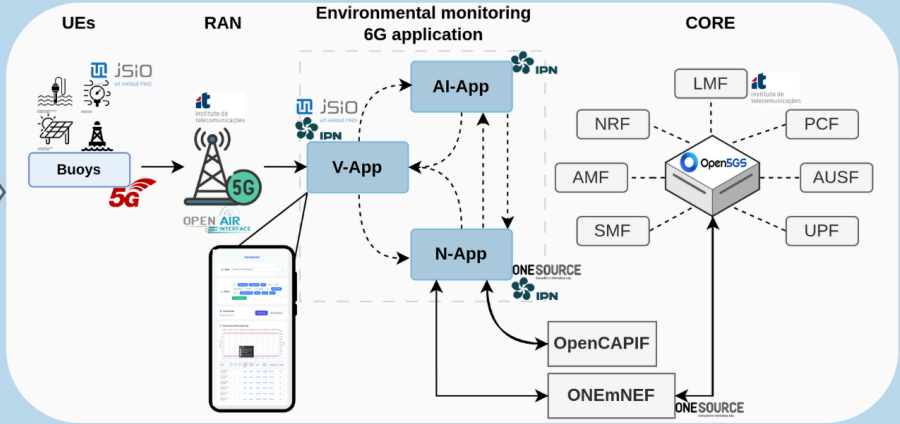

Figure 3: PoC architecture.

V-App	Receives, processes and displays environmental data from the IoT devices.
AI-App	Recommends energy profiles for the buoys based on current and predicted battery states.
N-App	Simplifies CN and IoT devices configuration by exposing, via APIs, the available energy profiles.
Smart Buoys	5G NR RedCap (RG255C) devices with solar harvesting, and a custom Fuel Gauge, collect and sends environmental data.
ONEmNEF	Exposure of network capabilities, specifically 3GPP AsSessionWithQoS API for bitrate configuration.

Towards AI-Driven Network API Invokation

The proposed loop, in Figure 4, uses the current and predicted battery state to select the most suitable energy profile for each buoy. The selected profile dynamically adjusts QoS parameters, sleep behavior, and reporting intervals to balance data collection and energy consumption.

The **AI-App** is composed of two engines: a **forecasting engine**, which predicts the future energy state of each device using battery, harvesting, and contextual data (e.g., meteorological conditions); and a **recommendation engine**, which selects the most appropriate **energy profile** for a given time period.

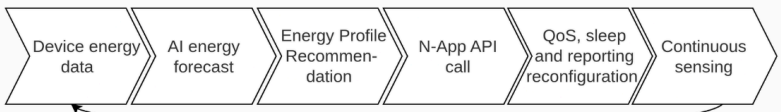

Figure 4: Energy management loop.

Conclusion

This PoC establishes an operational foundation for **energy-aware 6G IoT QoS management** through **NEF** and **OpenCAPIF** network API invocation. Future work will focus on the integration and evaluation of **AI-based recommendation mechanisms** for autonomous energy-aware reconfiguration.

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