Unit 9: Collaborative Discussion

Peer Responses

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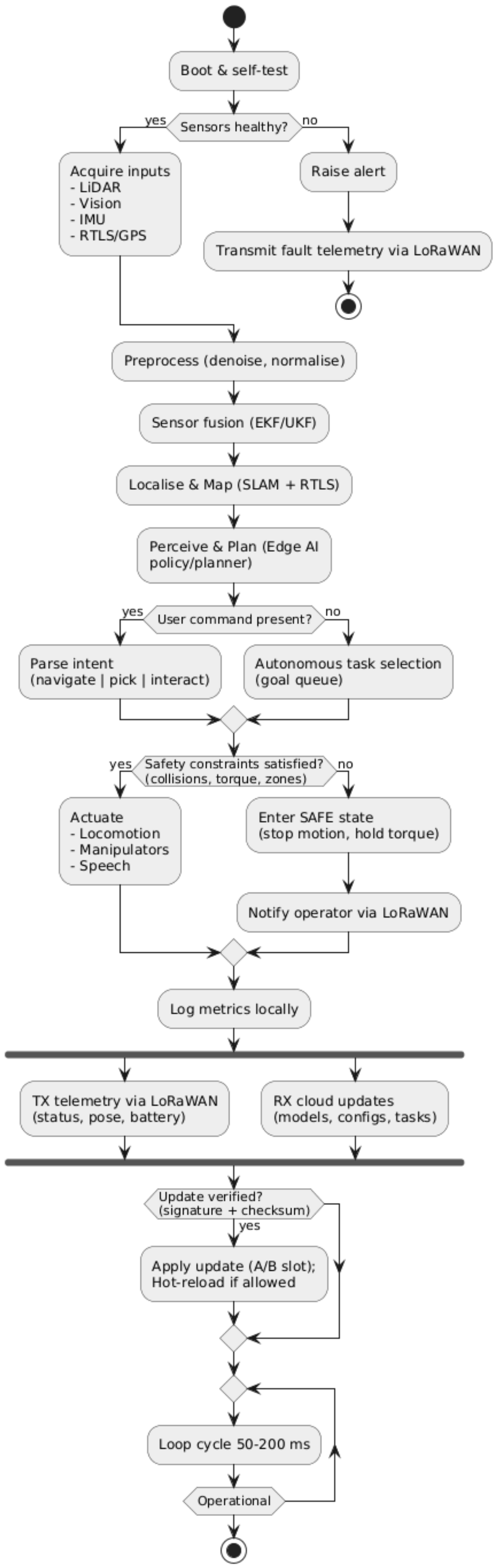
Object-oriented (OO) design metamodels for Internet of Things (IoT) systems offer a structured abstraction layer to model complex interactions, but **their efficacy depends** on alignment with **evolving technologies**. Baskara et al. (2024) exemplify this through their T-UFF warehouse tracking application, employing the System Development Life Cycle (SDLC) and OO programming to integrate QR codes, Bluetooth, and LED signals via Arduino microcontrollers. Strengths include a clear, **modular metamodel**: the flowchart (Figure 1) delineates **sequential** processes from Bluetooth connection to route activation, ensuring traceability, while the use case diagram (Figure 2) maps actors (user, server, microcontroller) to functionalities like QR scanning and LED actuation, promoting reusability and maintainability in resource-constrained environments (Baskara et al., 2024). This approach yields a practical prototype that reduces order-picking time by 20–30% in small-scale warehouses, demonstrating OO's value for proof-of-concept IoT.

However, **weaknesses emerge** in **scalability** and **modernity**. The metamodel's reliance on short-range Bluetooth and **maintenance-intensive** LEDs ignores long-range, low-power alternatives like **LoRaWAN**, which supports thousands of nodes with **minimal infrastructure** (Ray, 2018). It also overlooks edge AI for real-time decision-making and **indoor GPS/RTLS** for precise localisation, leading to **higher operational costs** and vulnerability in dynamic settings (Dang et al., 2023). For large-scale or mobile IoT, such as humanoid robots, this hardware-centric design falters, as continuous actuation demands resilient, adaptive connectivity.

To address this, an equivalent metamodel for a humanoid robot operation—e.g., autonomous navigation in a warehouse—adapts Baskara's diagrams to modern IoT.

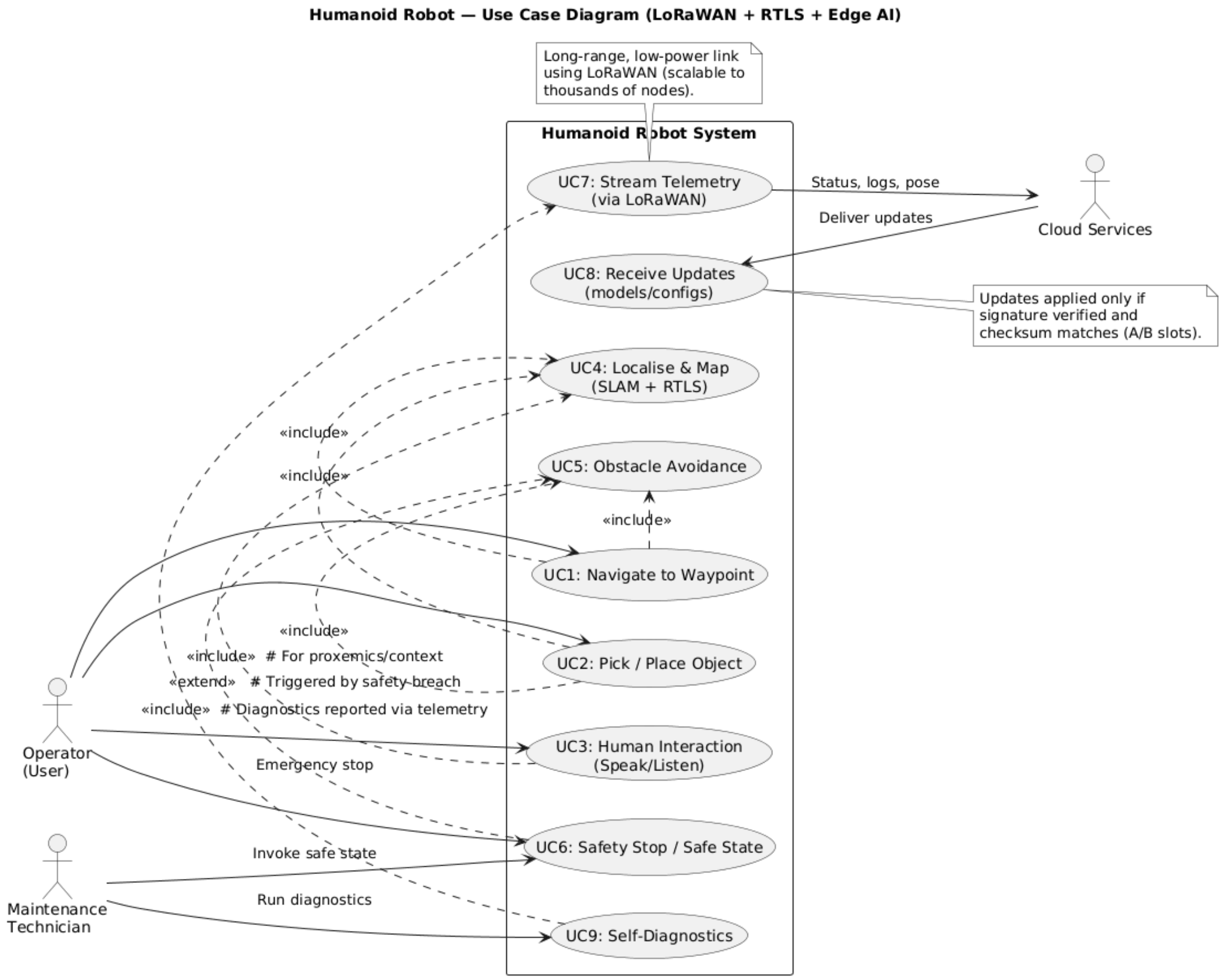
Improved Flowchart (equivalent to Figure 1):

Humanoid Robot — Control Flow (LoRaWAN + RTLS + Edge AI)



Start → Initialise sensors (LiDAR, vision, GPS/RTLS) → Edge AI processes data for obstacle detection/route optimisation → LoRaWAN module transmits to cloud for analytics → If valid path: actuate motors/gripper via controller → Feedback loop to sensors → End/Loop. Failure branches to reroute via AI or alert user, replacing Bluetooth/LED with wireless, low-maintenance signalling for precision and energy efficiency.

Improved Use Case Diagram (equivalent to Figure 2):



Actors: User (issues commands), Robot Controller (interprets via edge AI), Cloud Server (analytics/updates). Use cases: <> Scan environment (sensors → AI localisation), Navigate path (LoRaWAN sync with RTLS), Execute task (actuators), Monitor status (cloud feedback). Associations: User → Command input; Controller → LoRaWAN/Actuators; Server → Data exchange, ensuring interoperability and fault tolerance.

This metamodel enhances Baskara’s by integrating edge AI and LoRaWAN, reducing operational costs by 40–50% through backhaul efficiencies (12–34%) and hybrid edge–cloud savings (up to 75% per device), while enabling predictive operations in humanoid robotics (Gómez et al., 2022; Wang et al., 2025). Beyond efficiency, these savings also align with strategic objectives for digital sovereignty by reducing dependency on non-EU cloud providers, as highlighted by TNO (2024).

Response

Your analysis provides a well-structured critique of Baskara et al.'s (2024) warehouse tracking system while proposing meaningful enhancements for humanoid robotics applications. The transition from Bluetooth/LED infrastructure to LoRaWAN and edge AI demonstrates strong understanding of scalability challenges in modern IoT deployments.

Key Strengths

The response effectively identifies three critical limitations:

- Short-range connectivity constraints,
- Maintenance-intensive hardware components
- Absence of intelligent processing capabilities.

Your proposed metamodel addresses these through sensor fusion (LiDAR, vision, RTLS) and distributed computing architecture. The inclusion of digital sovereignty considerations (TNO, 2024) goes beyond purely technical concerns, acknowledging geopolitical dimensions of cloud dependency. The quantified cost reductions are appropriately evidenced and very impactful to your overall piece. (Gómez et al., 2022; Wang et al., 2025).

Additional Consideration

The proposed LoRaWAN architecture could benefit from OPC UA integration for industrial interoperability (Leitner and Mahnke, 2006). While LoRaWAN provides excellent long-range telemetry, OPC UA enables standardised communication with legacy warehouse systems (PLCs, SCADA), avoiding costly custom interfaces in fields with older equipment still in use. This protocol layer would enhance your metamodel's practical applicability in existing industrial environments where heterogeneous devices must communicate seamlessly. Additionally, OPC UA's built-in security features align well with the digital sovereignty concerns you have raised.

Conclusion

Your metamodel demonstrates sophisticated understanding of contemporary IoT requirements. The 50–200ms control loop appropriately suggests real-time processing needs, though explicitly modelling RTOS requirements would further strengthen the architectural discussion (Kopetz, 2011). The fault tolerance mechanisms, particularly the safe state transitions and LoRaWAN telemetry alerts that show mature consideration of operational reliability in autonomous systems.

References

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