Engineering IoT-based Software Systems for Forestry: A Case Study

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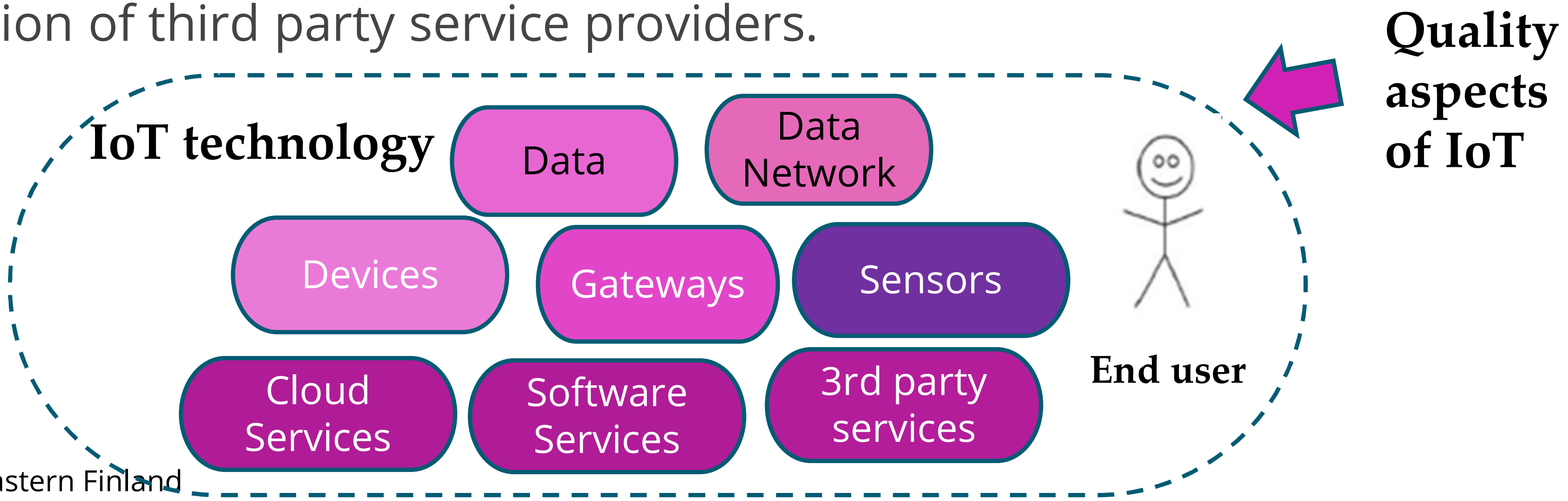
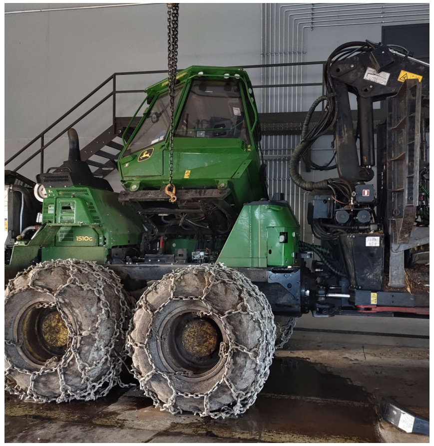
1. Introduction

- The Internet of Things (IoT) is a rapidly growing technology that offers huge possibilities for optimizing processes and increasing productivity in various domains.
- **Ensuring the quality of the IoT** is a complex challenge for software engineers and requires new development skills as well as coordination of third party service providers.



1. Introduction

- Forestry domain actors still operate with traditional non-digital practices
- IoT technology provides numerous opportunities for improvement and ways to improve productivity and increase level of automation.
- Forest machines are intelligent but the support and maintenance of forest machines includes a large number of manual work activities.



Managing supplies

Recycling waste

2. Research Methods

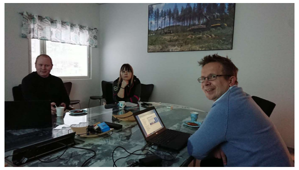
Research problem:
How quality aspects should be taken into account while designing and implementing IoT-based software systems for forestry?

3 research questions:

- What types of IoT monitoring needs does a forest machine operator company have?
- How quality attributes are visible in building IoT solutions?
- How IoT monitoring shall support forest operations?

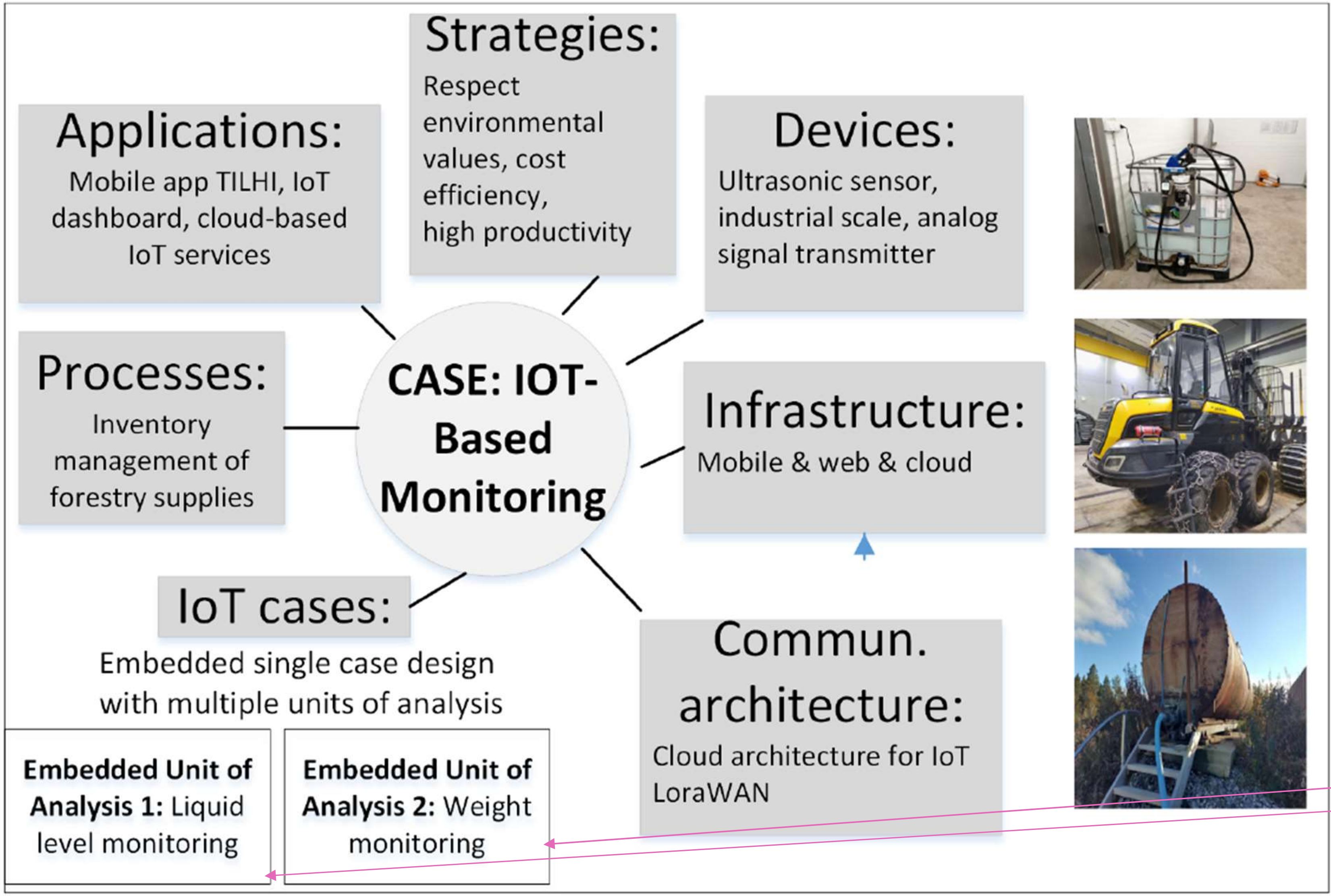
Engineering IoT systems for forestry

Research method: Embedded case study



Research data: Empirical data on two IoT cases conducted in the case organization (Device specs, interviews with IoT providers, work meetings, field visits, data records etc.)

Figure: The research settings of the study



Data analysis

Case com-parison

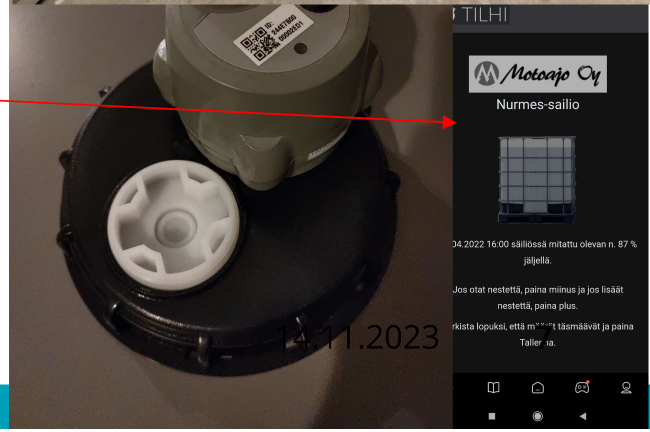
Figure: The context of the case study

3. Results

- Case study results are presented by using **S**ituation, **T**ask, **A**ction, **R**esults (STAR) approach.
- The STAR approach includes four steps:
  1. **Situation** describing the **context** within the IoT development was performed,
  2. **Tasks** describing **responsibilities or tasks** to be done in that particular situation,
  3. **Action** describing how the **task was completed** or how the **challenge was resolved**, and
  4. **Results** describing the **outcomes** or **results** generated by the **action.**

3.1. Case A: IoT-based liquid level monitoring

- **Situation:** the company lacks an accurate view of their forestry liquid inventories -> drivers of forest machines do not receive required.
- **Task:** The EU funding from DIH World enabled the research consortium to design, implement, test and validate the monitoring solution. The company can order refilling of containers proactively.
- **Action:** LoraWAN sensor modules installed into IBC containers, a mobile app development “digital twin”
- **Results:** IoT-based monitoring system that enables monitoring liquids (Adblue, marking dye) in remote storage areas.



3.2. Case B: IoT-based weight monitoring

- **Situation:** Need to monitor & measure mass of forestry supplies such as oil canisters (identified in the end of Case A)
- **Task:** The main task was to design a continuous mass measurement system using smart sensors and AWS cloud services-> An industrial class ”scale” under the monitoring target
- **Action:** Monitoring target was changed to the oil canister pallet, PCE RS 2000 scale purchased, meetings with Amazon, the system provider was selected after Solver X pitching event
- **Results:** the system architecture established, services selected, the prototype 80 % completed

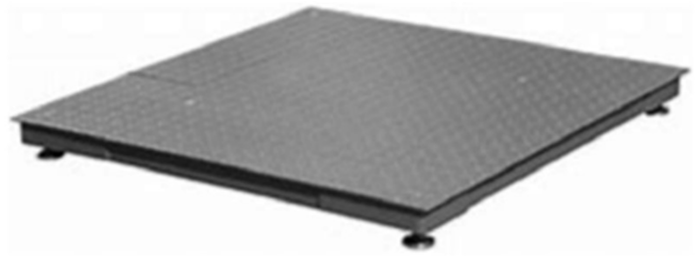
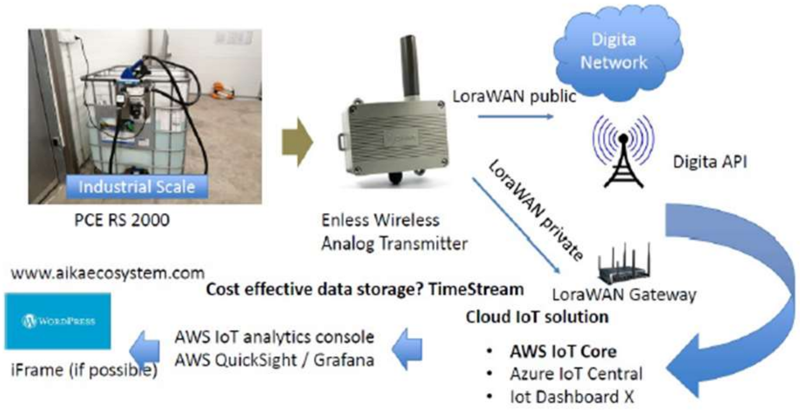


Figure: PCE RS 2000 scale



4. Ánalysis of results

Category	Case A	Case B
Monitoring needs	-Monitoring liquid containers -Proactive orders for liquids -Sending alerts on low levels -Ordering refilling containers in time	-Continuous mass monitoring -Proactive orders for supplies: oil canisters -Sending alerts on low levels -Oil orders in time
Quality	-Accurate view on liquid level -Data conversion on distance to percent -Data frequency 6 hours -Install sensor to cap of container -Calibration of sensors	-Number of oil canisters -4-20 mA to kg -Data frequency 1 hours -Scale under pallet -Calibration of scale
Benefits	-Check liquid levels remotely -Setting alerts on critical liquid levels -Proactive way to ensure availab. of liquids -Provides data on liquid consumption trends -May reveal container leaks	-Number of oil canisters -Setting alerts on only few oil canisters left -Enables monitoring any tangible items -Consumption of oil canisters -May detect that items are stolen

5. Conclusion




1. What types of IoT monitoring needs does a forest machine operator company have?
   - Various types and sizes of containers (fuel & water & oil & fungicide & diesel exhaust fluid & marking dye containers)
   - Various types of tangible supplies such as grease tubes, oil filters, oil canister pallets, chain blades and chains (mass monitoring needed)
2. How quality attributes are visible in building IoT solutions?
   - Devices and network: Selecting right sensor and data network solution
   - Data: Performing data conversion, defining data storage mechanism for IoT data
   - Calibration & installation: installing the sensors correctly, calibration of scales and sensors is very important to ensure quality of measurements
3. How IoT monitoring shall support forest operations?
   - Proactive ordering, alerts on low inventory levels, reduced traveling to remote sites…