Sensing the Environment Changes from Signal Strength Data: Machine Learning Approach

Student: Lea Dujić Rodić, dujic@fesb.hr
Advisor: Petar Šolić
University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Croatia

Introduction

- The Internet of Things (IoT) vision of ubiquitous and pervasive computing gives rise to future Smart Environments comprising physical and digital world, with applications ranging from healthcare, agriculture, automotive systems, to smart cities [1].
- Rapid population growth has resulted in the increased agricultural production demands where efficient water management is crucial, since it is estimated that 40% of water used for agriculture is lost in developing countries [2].
- Due to the rise of population in urban city areas there has been an increas of vehicles. Existing parking systems are inadequate or unable to handle parking loads, where in avarage drivers spend around 7.8 minutes in finding free parking lots [3]. One of the major issue that arise from this is the increase of fuel consumption and air pollution.

Description of the research problem

- Existing solutions are based on data received from the power hungry/expensive sensors that are transmitting the sensed data over the wireless channel, which become difficult to maintain, especially in remote areas due to the battery replacement issues with large number of devices.
- This work explores a concept of a novel, low-power, LoRa-based, cost-effective beacon-based mechanism, which achieves humidity and parking sensing with high accuracy using Machine Learning techniques simply by measuring signal strength from the given beacon device.

Research methodology

- In this research I2C soil-moisture sensor device buried 14 cm below ground was used for soil humidity and temperature monitoring and two indoor LoRaWAN gateways for data collection.
- Five Libelium Smart Parking sensor devices were placed at the faculty parking lot and three LoRaWAN gateways. Installed gateways employ TTN technology allowing collection of data and their storage into a designated InfluxDB database as shown in Fig.1.

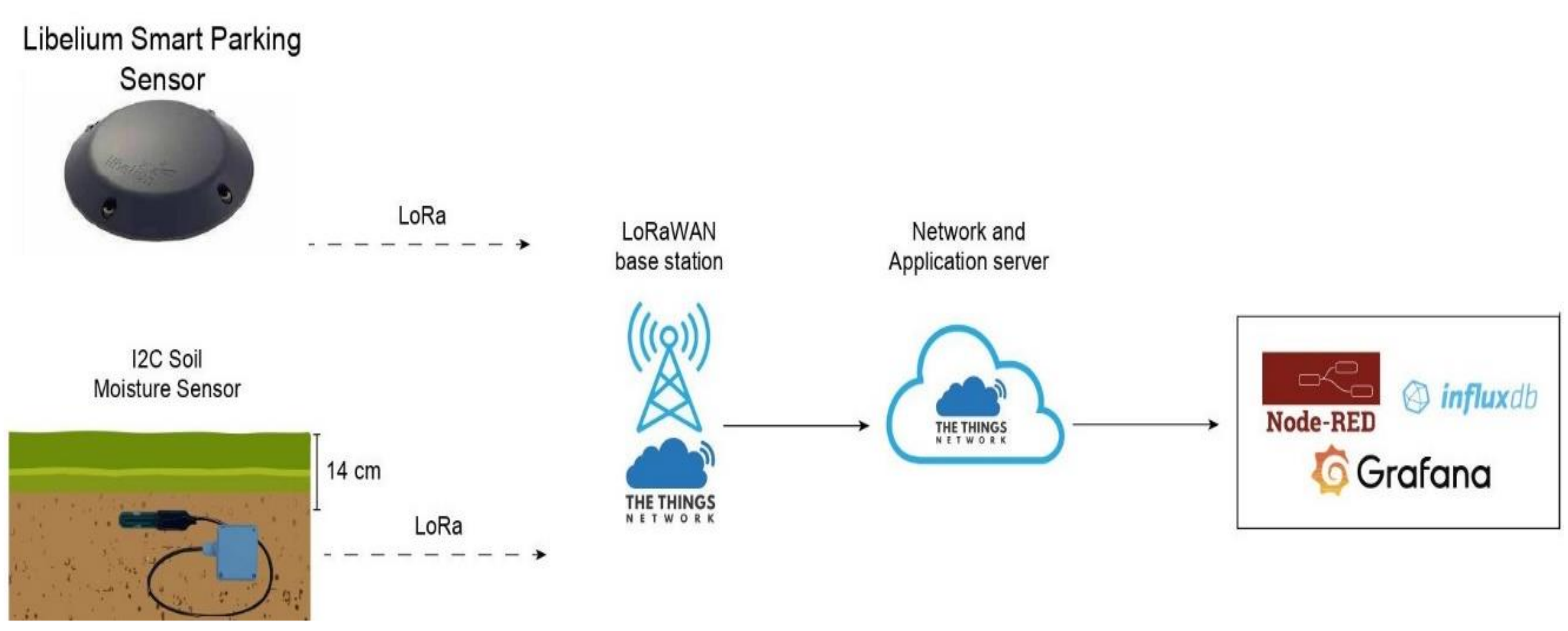

Figure 1. Network architecture of LoRaWAN-based soil moisture and Libelium Smart Parking sensors system.

- The collected data comprised information about parking lot occupancy status, Soil humidity, Received Signal Strength Indicator (RSSI) in dBm, Signal to Noise Ratio (SNR) for every gateway, gateway ID, Sensor ID, and timestamp of the moment at which the data was received by TTN gateway.

Results

- Extensive Data analyses revealed that changes of RSSI and SNR highly correlate with the change of Soil humidity and parking occupancy (Fig. 2 and Fig. 3.)

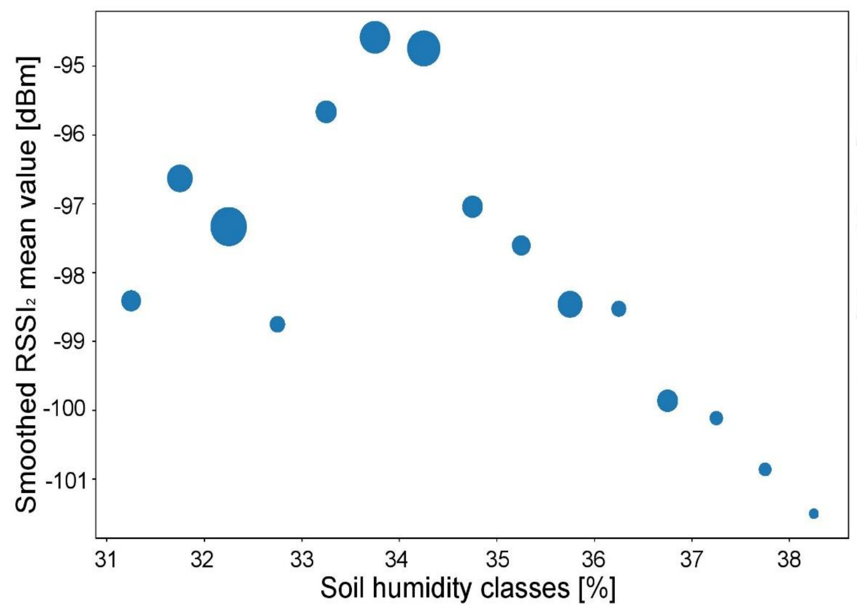

Figure 2. Smoothed RSSI values correlated with specific Soil humidity classes.

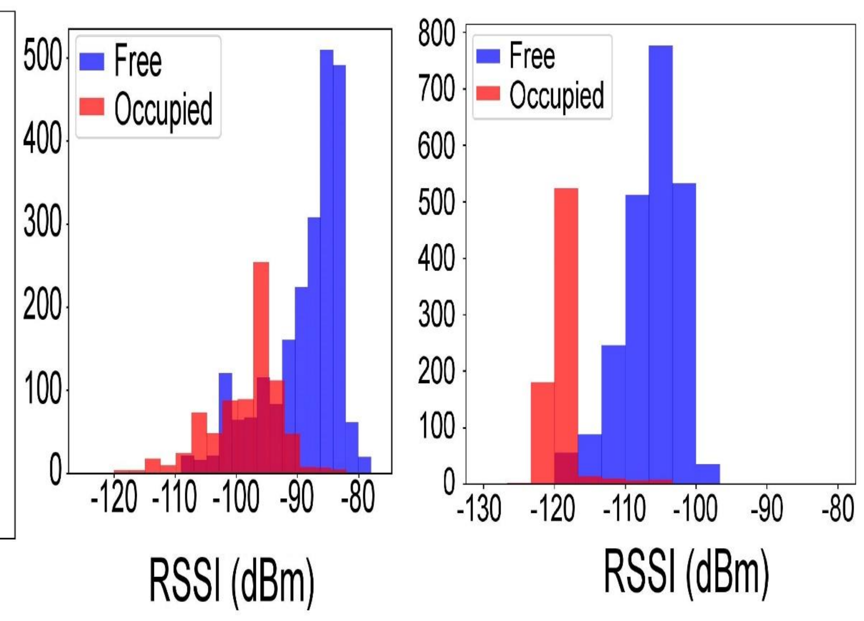

Figure 3. Histograms of RSSI values for free and occupied parking status from (left) Gateway 1 and (right) Gateway 3

- For estimation of Soil humidity from RSSI and SNR values, a Long-Short Term Memory (LSTM) neural network model obtained a MSE and MAE errors of 0.00018 and 0.01043, (Fig. 4).

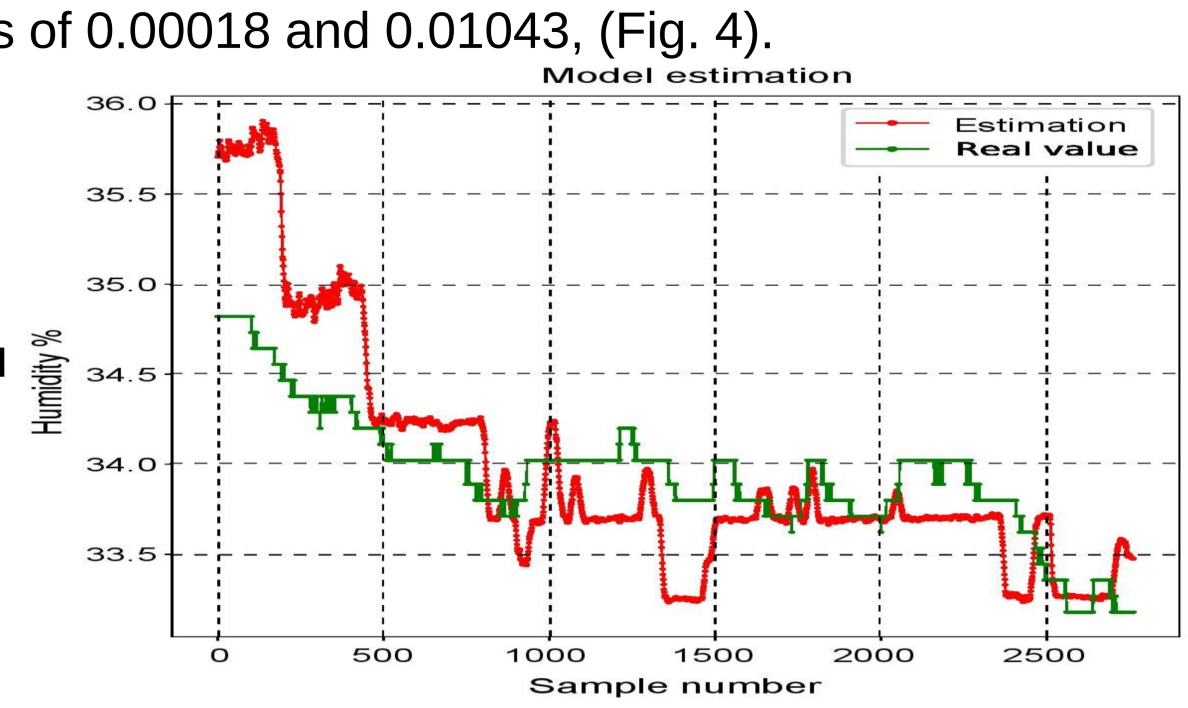

Figure 4. Estimation of soil humidity with the LSTM model compared to expected values of soil humidity.

- For parking occupancy classification, a Neural Networks (NN) model, (Fig. 5.) reached 96% and 95% Accuracy on validation and test set respectfully, and 98% AUC on both sets. As shown in Fig. 6, NN model is able to distinguishing occupied and free parking space exceptionally well.

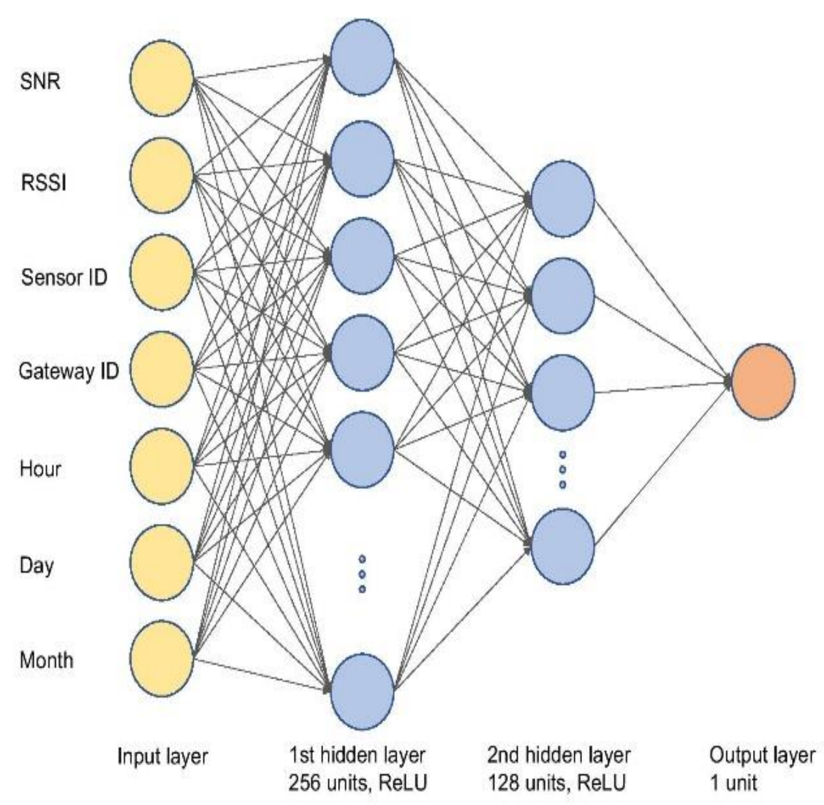

Figure 5. Architecture of Neural Network model for parking space occupancy classification.

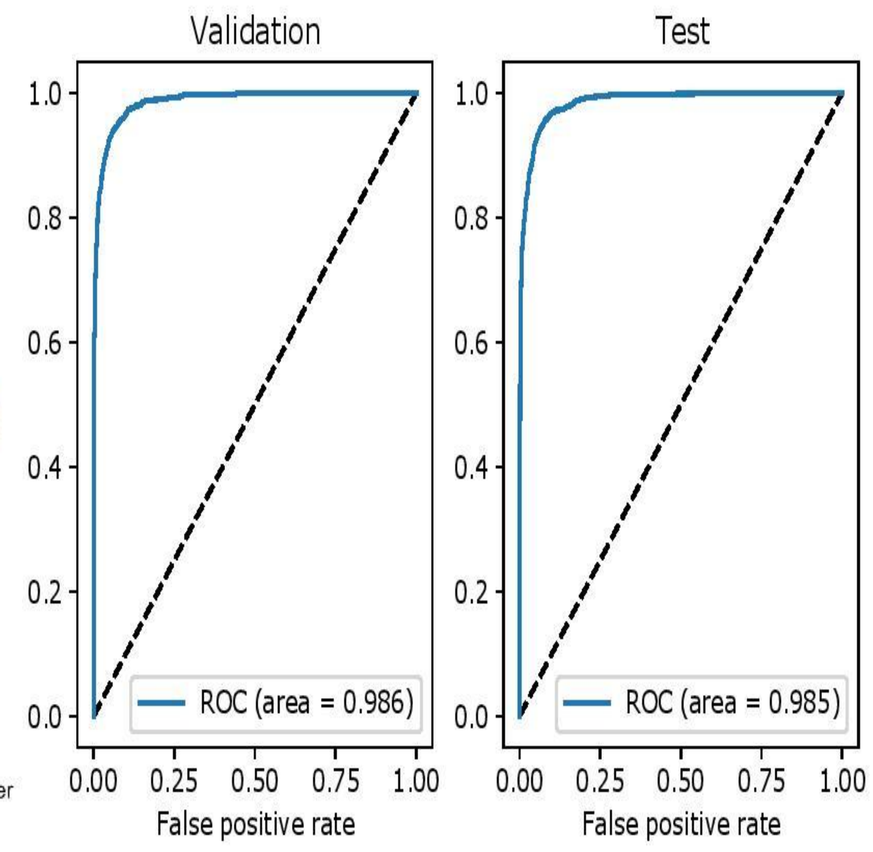

Figure 6. ROC curves for Adam optimizer with the learning rate of 0.001 and 100 epochs.

Conclusion

- A cost-effective solution would employ Machine Learning techniques for detecting changes in the environment solely by measuring signal strength, namely a simple beacon device that will not require any sensor readings.

References

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[2] A. N. Harun, M. R. M. Kassim, I. Mat, and S. S. Ramli, "Precision irrigation using wireless sensor network", in 2015 *International Conference on Smart Sensors and Application (ICSSA), 2015*, pp. 71–75.
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