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Near-Ground Wireless Coverage Design in Rural Environments

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Marta Botella-Campos was born in Valencia, Spain, in 1982. She received her Barchelor's degree in Telecommunications Systems, Sound and Image Engineering in 2019 and joined the research institute Instituto de Investigación para la Gestión Integrada de zonas Costeras (IGIC), at the Universitat Politècnica de València, short after finishing her studies. Currently, she is studying a master's degree on Technologies, Systems and Communications Networks at the Universitat Politècnica de València.

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Introduction

- Smart Farming emphasizes the use of ICTs to leverage the farm management cycle, improve business efficiency, increase production and reduce the environmental impact.
- The IoT and Cloud Computing are expected to move forward in farming management development by introducing these technologies into machinery and production systems.
- The gathered information will then be sent via different technologies such as IEEE 802.11 standards, Bluetooth, Zigbee, LoRa, 6LoWPAN, 3G, 4G, etc., depending on the amount of data to be transmitted and the distance.
- WSNs are needed to monitor environmental conditions and provide decision-making information. This type of networks is composed of a group of spatially dispersed sensors to monitor and record environmental conditions such as humidity, temperature, soil moisture, etc.
- However, each node can only monitor a specific part of the field. Thus, the coverage area is a key problem since all nodes among a WSN must be autonomous to cooperatively pass data through the network to a main location.
- IEEE 802.11 g/n standard is generally used in WSN because it allows distances up to approximately 300 meters in outdoor environments (when there is free space between devices).

Introduction

- Objective

To study near-ground wireless coverage in rural environments to ease multi-hop routing design. By measuring the coverage of an access point at different locations, this study aims to determine how near-ground radio-links are affected by field components such as grass, soil, trunks, etc.

Related work

- Lloret et al. presented a WSN that uses image processing to detect bad leaves in vineyards and sends an alarm to the farmer. Wireless communications are made through IEEE 802.11 a/b/g/n standard to allow long-distance connections. This solution provides a cost-effective sensor based on IP routers. The designed WSN takes into account both sensing and radio coverage areas to allow low bandwidth consumption and higher scalability.

- Wang et al. depicted a statistical model for near-ground channels based on experimental data collected through three different scenarios at 2.4 GHz. The main objective was to develop a WSN to collect data in military explosive research. Sensor nodes were fixed on the ground with an antenna of 3 cm height. Different propagation models were applied to predict path loss and compare the results with the performance of the obtained model.

- Luciani et al. described a study performed on near-ground node range at different heights in Wi-Fi crowded environments. The designed WSN used IEEE 802.15.4 standard to avoid direct interference. To perform the tests, measures were taken at three different heights at three different scenarios. The results showed that prediction models failed to accurately forecast path loss.

- Szajna et al. characterized path loss and near-ground channels at 2.45 GHz on forested areas covered by snow, to investigate the impact of antenna height and distance between nodes on path loss and special correlation. Measurements were carried out in two different scenarios with varying antenna heights.

Related work

- Torabi et al. proposed a near-ground prediction model to facilitate accurate WSN simulations using the principles of the Fresnel zones. The effects of antenna height, frequency, polarization, and electrical and geometrical properties of the terrain were studied. The results of this study showed that antenna height was by far the most influential parameter on network connectivity.

- Sangodoyin et al. presented a near-ground channel model to achieve precision ranging and localization of UWB propagation channels. Antenna heights ranged from 10 cm up to 2 m above ground to determine its effects on signal strength. The results showed that the distance-dependent path loss was highly dependent on antenna heights. Moreover, under near-ground situations, frequency-dependent path loss exponent and shadowing variance increased.

- Klaina et al. presented a narrowband radio channel model operating under near-ground conditions. A WSN based on ZigBee was designed to analyse the effects caused by soil and grass fields at 868 MHz, 2.4 GHz and, 5.8 GHz. To estimate signal quality, RSSI was measured and compared to path loss. The effects on RF propagation were highlighted in the cases where antenna heights were 40 cm or less, and signal levels decreased in the presence of grass fields and soil.

- Tang et al. studied a near-ground WSN at 470 MHz in four different scenarios to obtain the corresponding path loss models. Three different antenna heights were used, and the RSSI was measured every meter, every 2 m, and every 5 meters. The results showed that when antenna height is lower than 50 cm, prediction models tend to inaccurately forecast path loss and network connectivity.

After analysing previous works, we can conclude that near-ground wireless systems are difficult to characterize.

Analytical Study

Three propagation models are presented to predict the average signal strength drop and assess the level of accuracy that can be achieved in near-ground WSN scenarios.

Free-Space Model

$$FSPL\ (dB) = 20 \log\left(\frac{4\pi\ d\ f}{c}\right) - G_T - G_R$$

Two-Ray Ground Reflection Model

$$PL(dB) = 40 \log(d) - 20 \log(h_r) - 20 \log(h_t)$$

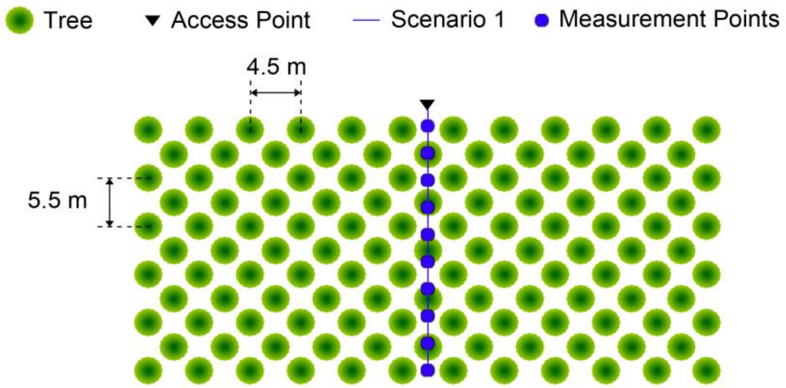
One-Slope Log-Normal Model

$$PL\ (d) = FSPL(f, 1\ m) + 10n \log\left(\frac{d}{1\ m}\right)$$

Scenario Description and Tools Used

In this study, the Signal to Interference Ratio (SIR), the Received Signal Strength Indicator (RSSI) and the Round-Trip Time (RTT) of a wireless signal have been measured at different scenarios 30 cm above ground.

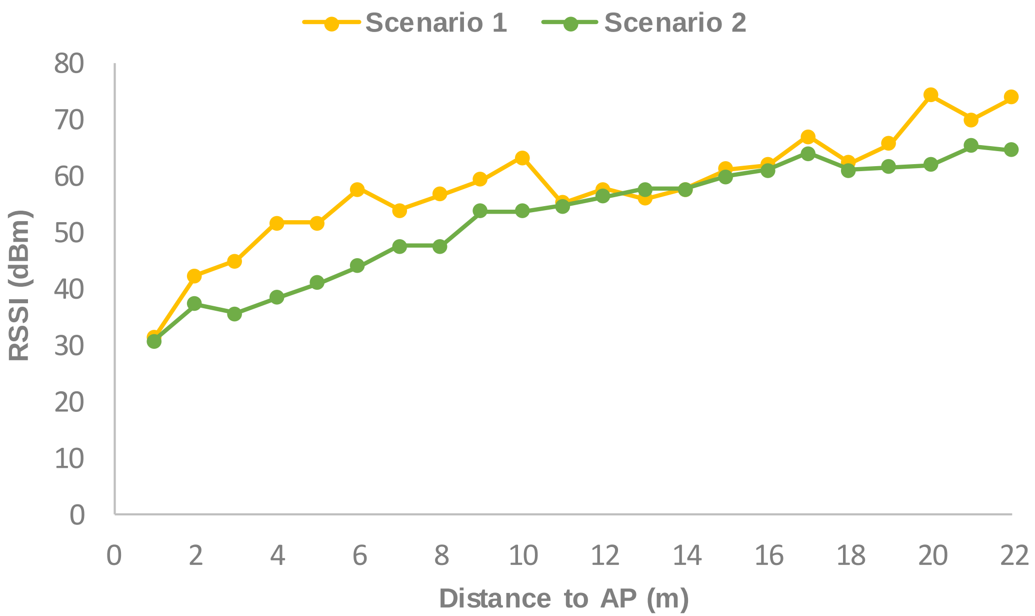
Orange tree plantation where measurements took place



Measurement points and vegetation geometry

Experimental Results

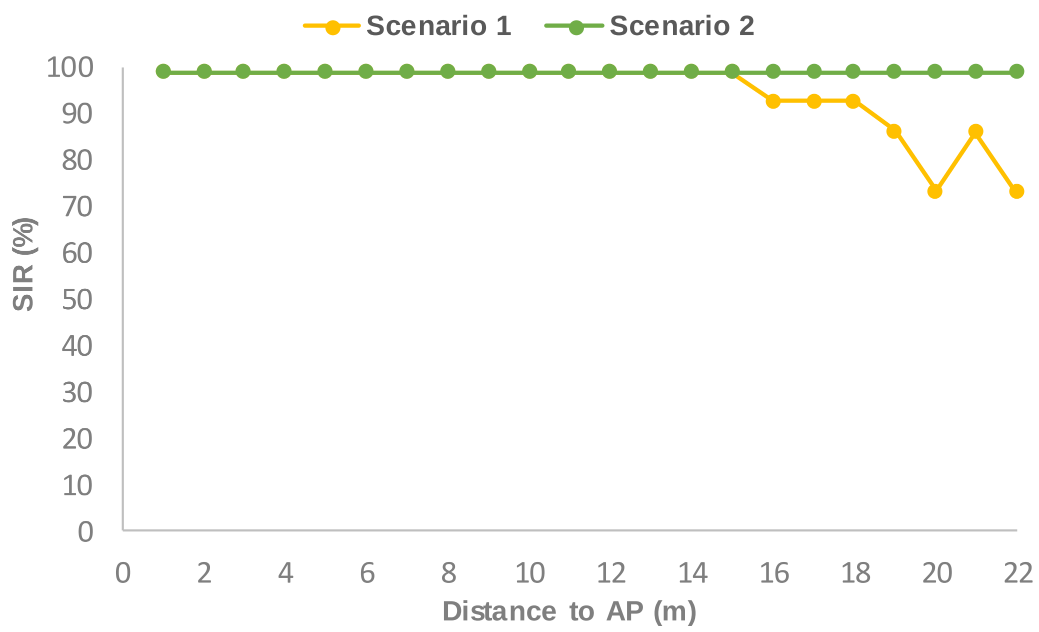
As the figure shows, the RSSI from Scenario 1 fluctuates much more than the one from Scenario 2. This can be due to the random distribution of vegetation, as well as the presence of trunks. Moreover, the absorption of energy in Scenario 1 may be caused by the presence of grass.



- Scenario 1: Measurements were made at an orange tree plantation, with data being collected behind the foliage of each tree.
- Scenario 2: Measurements were made on a field with no vegetation, ensuring clear connectivity.

Experimental Results

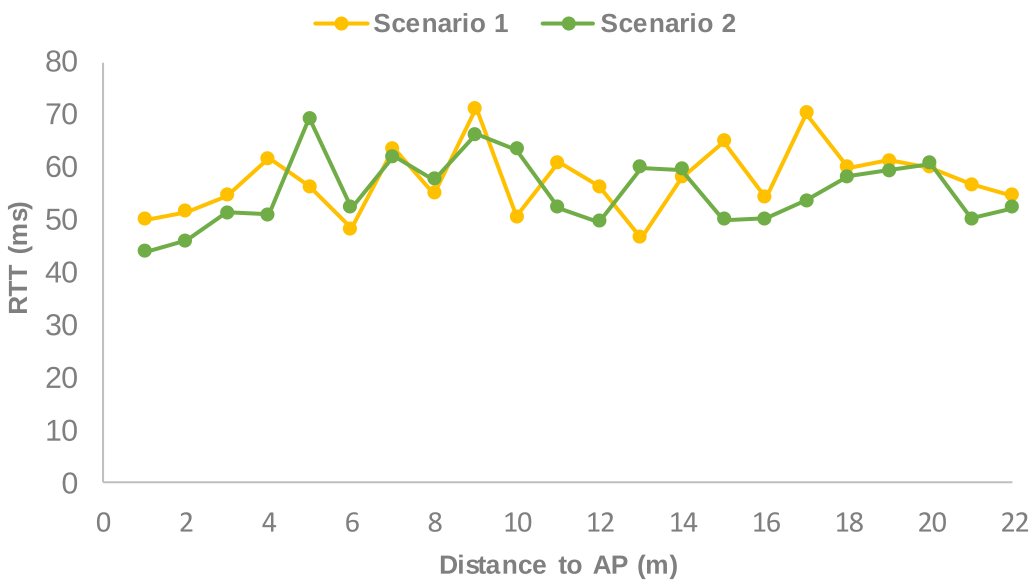
As for the SIR measured in both scenarios, it can be inferred that the presence of vegetation has little effect on the quality of the signal, though the reflection on the ground may cause errors depending on the modulation used.



- Scenario 1: Measurements were made at an orange tree plantation, with data being collected behind the foliage of each tree.
- Scenario 2: Measurements were made on a field with no vegetation, ensuring clear connectivity.

Experimental Results

In this case, the time delays vary far more in Scenario 1 than in Scenario 2. This agrees with the observed fluctuations of RSSI in Scenario 1.

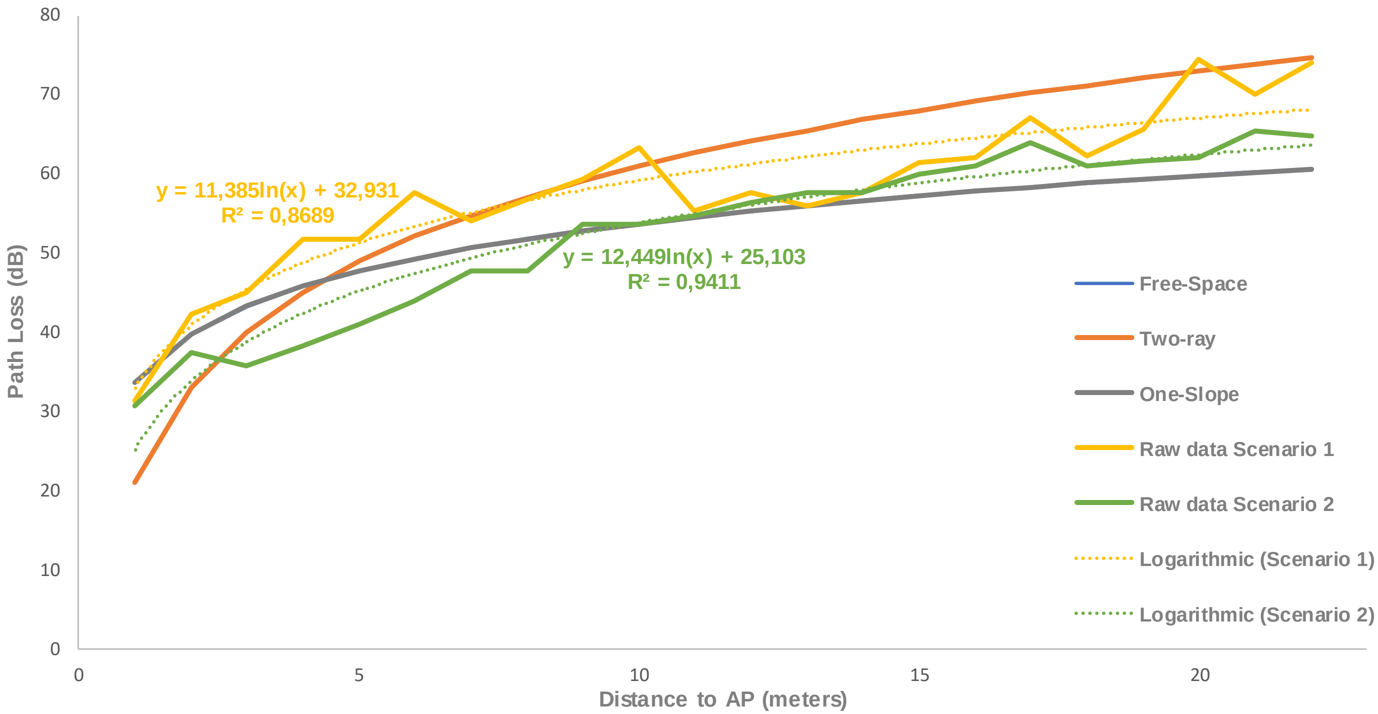


- Scenario 1: Measurements were made at an orange tree plantation, with data being collected behind the foliage of each tree.
- Scenario 2: Measurements were made on a field with no vegetation, ensuring clear connectivity.

Experimental Results

We compared the selected prediction models by plotting them together with the collected data from both scenarios. In this figure, One-Slope Model overlaps Free-Space Model.

Attending to the collected data curves, the path loss is higher in Scenario 1. However, the Two-ray Model failed to predict the attenuation correctly. Furthermore, the collected data from Scenario 2 shows a greater path loss than one the predicted by the Free-Space Model and the One-Slope Model.



- Scenario 1: Measurements were made at an orange tree plantation, with data being collected behind the foliage of each tree.
- Scenario 2: Measurements were made on a field with no vegetation, ensuring clear connectivity.

Conclusions

- In our case study, we analysed the signal quality by measuring the RSSI, the SIR and the RTT of a wireless signal and compared the collated data with three different path loss prediction models.
- Results showed that, in near-ground scenarios, the RSSI tends to fluctuate much more in the presence of vegetation (Scenario 1).
- The geometry of the trees and the presence of grass produced a scattering of energy, as well as a higher number of reflections and refractions.
- However, the interference was only noticeable from 15 meters.
- None of the selected prediction models managed to accurately forecast the path loss, though Free-Space Model and One-Slope Model were close to the measured RSSI of Scenario 2.

Furure work

- We would like to include different types of plantations and agriculture environments.
- Additionally, it could be interesting to perform these practical experiments with other technologies such as LoRa, Zigbee and Sigfox which are currently being used in farming activities and compare them with the results of IEEE 802.11 standard.

Thanks you for your attention!!

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