# Implementation of RSSI Module in Omnet++ for Investigation of WSN Simulations based on Real Environmental Conditions

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Abstract: The simulation of different scenarios and protocols under environmental conditions is a success key for a reliable Wireless Sensor Network (WSN). For some applications, the variation of the weather conditions as the temperature and humidity could affect the Received Signal Strength Indication (RSSI). Running multi-simulation scenarios is required to evaluate the proposed protocols and architectures before their deployment in a real-world network. The more the simulator mimics the real world, the closer the evaluation results to the real network. In this paper, we have integrated temperature and humidity in the Omnet simulator and have taken into account the impact of these environmental factors on the RSSI based on real experiments that were carried out using the CC1101 radio ship of Panstamp Avr2 at 868 MHz frequency.

## 1 INTRODUCTION

Nowadays, Wireless Sensor Networks (WSNs) appear as an active research field in which challenging topics include energy consumption, routing algorithms, selection of sensors location according to a given premise, robustness, efficiency, and so forth.

WSN is used in several applications such as disaster management, entertainment, education, environment monitoring (Debashis De, 2020). Although the applications of WSN increase rapidly in the modern era, it has several limitations such as limited energy capacity of the nodes, shortage memory capacity of the nodes as well as limited computational capacity.

Many standards are approved in wireless communication and different metrics have been used to enhance the reliability of the network. Those metrics depend on several factors, such as the transceiver type, external environment, modulation scheme, data rate, etc. Thus, a good link quality between sensors is an essential condition for successful communication.

Many studies were approved out based on the performance analysis of link quality to estimate the efficiency of the communication link between nodes. Received Signal Strength Indicator (RSSI), which includes also information about the link quality, is an essential parameter in the receiver packet. RSSI degradation, mentions degradation of the quality of the signal (David Rojas, 2018), especially when it is exposed to many environmental conditions, or when the network is deployed in a harsh area. As a consequence the RSSI provides a precise estimation of the robustness and reliability of transmitted data packets.

The use of simulators nowadays is required, when developing or researching in the field of WSN (Miloš Jevtić, 2009). Reasons for this are numerous. Manufacturers have not achieved expected low costs for sensor nodes yet, so experiments on a real-world WSN (which could consist of hundreds or thousands of nodes) are expensive. Moreover, simulations give the users a general idea of multiple scenarios that could happen in real-world territories and allow them to evaluate their proposed protocols and/or architectures before the real deployment (Ilef Ketata, 2019).

Many researches have already proved the impact of weather conditions on the RSSI in indoor and outdoor systems (Boano, 2010) (Amir Guidaraa, 2018) (Luomala, 2015) (C. Boano, 2009) (K. Bannister,



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2008). However, for the best of our knowledge, none of the wireless simulators has taken into account those impacts. Our proposed work developed the idea of integrating those factors on the advanced simulator Omnet++ with several built-in functions and a powerful representative Graphical User Interface. The outline of our paper is as follows: The second Section discusses the related work and sets out the novelty of our paper. The third section will show real measurements for the RSSI variation which will be adopted in the RSSI bloc integration in Omnet++. We will focus in section four on the implementation of the RSSI module and the presentation of some simulating scenarios. Finally, a conclusion and future work will be presented for opening new aspects in the research field.

## 2 RELATED WORKS FOR SIMULATION OF WSN UNDER REAL ENVIRONMENTAL CONDITIONS

### 2.1 Importance of Simulations for WSN

WSN simulators are widely used in different wireless applications, they are the most known approach for protocol testing. Most researchers in the field of WSN use simulators to predict the node's behavior since simulators provide several advantages like flexibility and test period. Every WSN application has to involve a conception and designing phase, after which, the test phase will take place. The simulation phase is relevant to help both designers and researchers to get a general idea of the network. The ability to integrate real testing conditions into the simulator interfaces enhance the challenge of network accuracy and reliability. Also, the prediction of parameters that could affect communication could be taken into account, e.g, the variation of RSSI and link quality degradation. This classifies simulation as the most used evaluation technique in the wireless communication field due to its low-cost implementation and eases to use (Ilef Ketata, 2020).

The Fig. 1 shows the most cited WSN simulators in the state of the art (Michel Bakni, 2019). OMNET++ is among the top list of simulating tools that have drawn significant interest in the research area. Although OMNET++ provides powerful and clear simulation frameworks, such as Simu5G, Veins, RinaSim, INET framework, etc (Org, 2021). the most utilized framework is the INET framework that provides protocols, agents, and other models for researchers and students working with communication

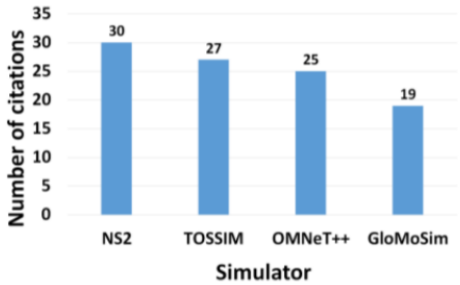


Figure 1: Number of citations that present each simulator (Michel Bakni, 2019).

networks.INET is especially useful when designing and validating new protocols, or exploring new or exotic scenarios. The Omnet++ hierarchical structure and powerful Graphical User Interface(GUI) made him the best choice for developing and integrating new strategies and applications but also it has some limitations, it lacks observing of the RSSI variation as a consequence of the climate changes. So the idea was to integrate the RSSI module into OMNET++, which contains a description of how signals act when temperature or humidity change, after a detailed discussion on real measurements.

### 2.2 State of the Art of RSSI Variation in Wireless Communication

WSN is a gaggle of specialized autonomous sensors and actuators with a wireless communications infrastructure, intended to watch and control physical or environmental conditions at diverse locations and to cooperatively pass their data to the main location and/or pass their control command to the desired actuator through the network. The wireless network is composed of a finite set of sensor devices geographically distributed in a given indoor or outdoor environment (usually predefined). A WSN aims to gather environmental data when the node devices placement may be known or unknown (Farahani, 2008).

In the ideal non-obstructive environment, the nature of electromagnetic waves propagation attenuates the signal power abruptly near the transmitter and yields much less attenuation at longer distances. This is described by the Friis Equation (Nouha Baccour, 2013), directly derived from fundamental theory. In the real environment, a lot of external factors that could affect the electromagnetic waves and attenuate the signals near the receiver, take the reflection, diffraction, or absorption caused by a different type of obstacle as an example, nature effects such as wind, rain, temperature, thunder and so on.

WSN applications have been integrated into several areas either in indoor or outdoor scenarios. Different works studied the impact of various environments on LQI and RSSI. David Rojas and John Barrett studied the link quality and the Received signal strength using TelosB nodes of WSN in metal marine environment (David Rojas, 2018), where they manage to distribute 18 nodes in a complex metallic environment composed of fright containers, engines, and different materials that cause the attenuation of signals.

Boano et al. studied the impact of temperature on the RSSI and LQI in an oil refinery using CC2420 radio ships (Boano, 2010), the experimental results show that temperature has a major effect on the signal strength and link quality. In (Amir Guidaraa, 2018) the impact of humidity and temperature on the RSSI in indoor WSN have been studied, they deployed 868MHz Panstamp NRG 2.0 wireless modules, where different distances show different values of correlation between humidity and the RSSI, and the temperature and the RSSI.

In (Luomala, 2015), the author explored the effects of ambient temperature and humidity on radio signal strength of Atmel ZigBit 2.4GHz wireless modules in outdoor WSNs.The experimental results demonstrate that changes in weather conditions affect received signal strength. Temperature seems to have a significant negative impact on the signal strength in general, while high relative humidity may have some effect on it, particularly below 0ºC.

Boano et al.(C. Boano, 2009) exposed that the increase in temperature decreases both RSSI and LQI, they have used Tmote Sky nodes (CC2420 radio) and MSB430 nodes (CC1020 radio) in indoor experiments. Bannister et al. (K. Bannister, 2008) experiment demonstrate a linear decrease of 8dB in signal strength when the temperature rose from 25ºC to 65ºC using TI CC2420 radio chip on a Tmote Sky node. They also showed the implications of the experiment on different communication range.

All the proposed works present physical implementation of sensor nodes with limited results that could be non-sufficient for analyzing and models interpretation in the relation of the proposed problem. As described before, dealing with an infinite number of simulations could determine better results for node's behavior, which will be implemented in our work based on real measurements.

# 3 STUDY OF THE IMPACT OF TEMPERATURE AND HUMIDITY ON THE RSSI

## 3.1 Received Signal Strength Indicator (RSSI) in CC1101

The received signal strength is the power level of the signal received at the antenna of the device. In the ideal transmission, the RSSI can be determined with the transmission power and the distance between the nodes. The RSS-based location techniques have shown the relation between the RSSI and the distance in wireless sensor networks, and this relation is computed according to the following equation:

$$RSSI = RSSI0 - 10 * n * log(d/d0) + X\sigma \quad (1)$$

- RSSI0 indicates the RSSI when the reference distance is d0
- n indicates the path loss index in a specific environment.
- Xσ is in dB; it is a cover factor when the range of standard deviation σ is 4≈10 and the mean value is 0; the larger the σ, the greater the uncertainty of the model.Indicates the speed of attenuation of the signal.

The RF transceiver CC1101 estimates the RSSI values based on the current antenna gain in the Rx channel and the measured signal level in the channel itself. In reception mode, the RSSI values could be read continuously from the RSSI status register. The RSSI register is a two-complement number. To convert the RSSI reading to an absolute power level a conversion algorithm is executed:

```
Begin
  RSSIreg  ← read (RSSI status register)
  RSSIdec  ← convertToDecimal (RSSIreg)
    If RSSIdec > 128 then
       RSSIdBm←(RSSIdec-256)/2 - RSSIoffset
    Else
        RSSIdBm ← RSSIdec /2 - RSSIoffset
    End if
End
```

## 3.2 Experiment Setup for RSSI Variation Measurements

The experiment is carried using two Panstamp AVR2 wireless sensor nodes, a sender and receiver with built-in C1101 868 MHz radio ship and a DHT11 temperature and humidity sensor. The sender node sends a beacon message every 0.4 seconds with particular transmission power. The receiver node measures the RSSI for each beacon message the receiver also gets the values of humidity and temperature values through the DHT11 sensor, recording RSSI, humidity, and temperature and sending them through a UART communication to the computer where the data is saved in a CSV file to be later analyzed. During the experience, two different scenarios were launched, the first was wired communication, where the sender and the receiver are connected through an SMA cable using a step attenuator in between to variate the attenuation of the signal from 0 to 80dB where the receiver was placed in the climatic test chamber. The second experience was wireless, using the radio communication between the two nodes at different input power levels.

To test the temperature impacts, the same setup is followed in the climatic test chamber CTC256 for both wired and wireless communication, the humidity is off and the variation of temperature was in [-10..40] °C range. The variation of temperature was by 5 °C scales, and for each scale of temperature 100 samples are taken to be analyzed in the next step. For the humidity impacts, the temperature was fixed at 30 °C. The humidity varies in the [40..90]RH % range. The variation of humidity was by 10RH % and in every scale of humidity, up to 100 samples are recorded to be analyzed later.

The wired connection didn't show a variation of RSSI that could be adopted later in OMNET++. The reason for this link quality stability is that the signal is well protected with the cable and the factor of attenuation is very low. To ensure that both temperature and humidity had no effect on the RSSI in wired communication the correlation has been calculated and shown in the results below:

- Corr(RSSI,humidity) = -0.028
- Corr(RSSI,temperatur)= -0.017

The correlation is considered too low (close to the zero value) as a consequence of the stable value of the RSSI even the changes applied on temperature and humidity.

The second setup is to implement a wireless connection between the sender and the receiver, which were placed at the edges of the climatic test chamber. After getting the dimension of the climatic chamber(width, height, and depth) CTC256, the distance between the two nodes could be calculated using the Euclidian distance:

$$Distance = \sqrt{0.642^2 + 0.672^2 + 0.62^2} = 1.1m \quad (2)$$

In this case, the attenuator has no place so the idea is to control the output transmission power from the CC1101 ship through sending different values to the PATABLE register. the output transmission power was -10dBm, -20dBm and -30dBm. In the beginning, the humidity was off, the temperature was at 25 °C, the output power was programmed at -10dBm, the spectrum analyzer shows that there were 8dBm losses due to the transmitter, the received signal strength was at -71dBm.

$$Losses = -71 + 10 + 8 = 53dB. \quad (3)$$

The conclusion of the 50dB losses that are coming from reflections of the metallic climatic chamber. The same distance will be kept for the whole measurements setup inside the testing chamber.

## 3.3 RSSI Data Measurement's Discussion

After saving data, the idea was to format it using multiple methods and search for a suitable correlation. In each case, the simple moving average had the highest value of correlation. So the simple moving average is manipulated in each level of transmission power applying the linear regression and calculating the slope and the intercept. the window of the simple moving average was equal to 20. The reason behind choosing a window of 20 is that we took 100 samples for each scale of humidity and temperature, in some scales the RSSI varies up to 6dBm, so centralizing the data was a better choice to align it to a definite behavior, if we close the window to 100 so we are closer to the mean of the data which is not a base form in data analysis that depends on a high number of sets if less than 20 so we are going in a path of decreasing the correlation and decentralizing the set of data. This step made the implementation easier since the simulator is depending on the close behavior of the CC1101 ship but not the exact way of working.

Fig. 2 shows the impact of Humidity on the RSSI using -10dBm transmission power. The correlation was -0.92. the slope and the intercept were calculated after applying the linear regression, those variable are showed in the equation below:

$$RSSI = RSSI0 - 0.2234 * H \quad (4)$$

were:

- RSSI0 = -53.8565 in dBm.
- H is the humidity in RH%

Fig. 3 shows the impact of Temperature on the RSSI using -10dBm transmission power. But as shown in the graph there's some fluctuation around -5°C. That was the effect of the relative humidity in the climatic chamber and that's when showed the role

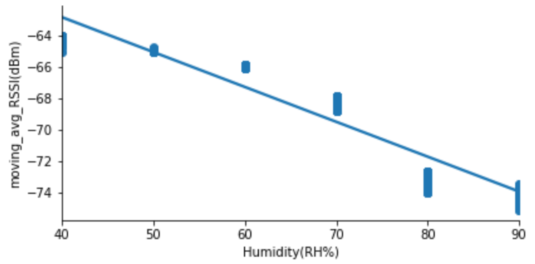


Figure 2: Linear graph of the variation of the RSSI according to the humidity, Tx power =-10dBm.

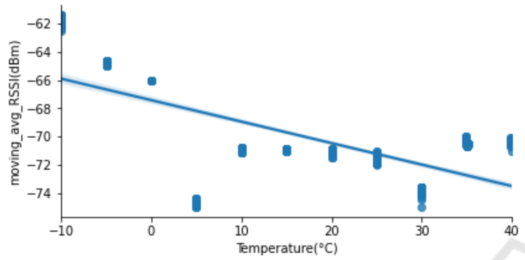


Figure 3: graph of the variation of the RSSI according to the temperature, Tx power =-10dBm.

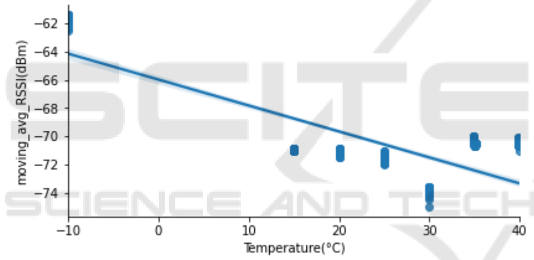


Figure 4: Linear graph of the variation of the RSSI according to the temperature, Tx power =-10dBm.

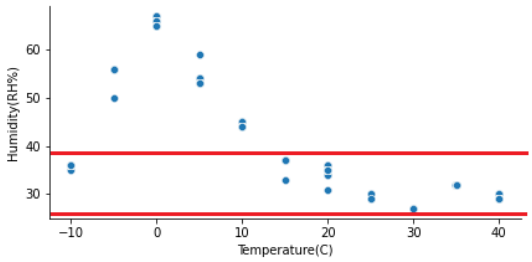


Figure 5: Graph of the variation of humidity according to the temperature.

of the DHT11 sensor, to record the data of the relative humidity inside the climatic chamber, the recorded data is shown in Fig. 5. The two red lines present the working domain when the humidity is considered stable. And as the calculated data is up to 100 samples for each scale the output info is still fair enough to apply a data model on it. The Correlation increase from -0.65 to -0.8 which is considered as a high negative correlation and the new data is printed in Fig. 4. The slope and the intercept have been calculated after applying the linear regression, those variables are shown in the equation below:

$$RSSI = RSSI0 - 0.1841 * T \tag{5}$$

were:

- RSSI0 = -65.9759 in dBm.
- T is the temperature in °C

## 4 IMPLEMENTATION OF RSSI MODULE IN OMNET++

Every WSN application has to involve a conception and designing phase, after which, the test phase will take place. The simulation phase is relevant to help both designers and researchers to get a general idea of the network.The implementation of the experience results under an open acess simulator platform is a challenging task to be available for other OMNET users in the future. The experiences show that the RSSI has a considerable correlation with both temperature and humidity. The RSSI module will be implemented under the physical layer into the compound module of the radio medium. The RSSI module uses the RSS-based location technique equation 1 with the temperature and the humidity attenuation. Therefore, the parameters of the RSSI module are:

- Distance: is calculated using the position from both receiver and sender. The location of the sender is obtained from the ITransmission module, where the receiver position is gotten from the IArrival module. a special API built in the RssBase file that calculates the distance between the nodes using the Euclidean method.
- Temperature: is set by the user using the INI file of the simulation, registered in the IphysicalEnvironement module, and converted into the RssBase file. The impact of the temperature was added using the equation 4 by defining a second attenuation factor as the slope parameter and the RSSI0 get the intercept.
- Humidity: is set by the user using the INI file of the simulation, registered in the IphysicalEnvironement module, and converted into the RssBase file. The impact of the humidity was added using the equation 5 by defining a second attenuation factor as the slope parameter and the RSSI0 get the intercept.

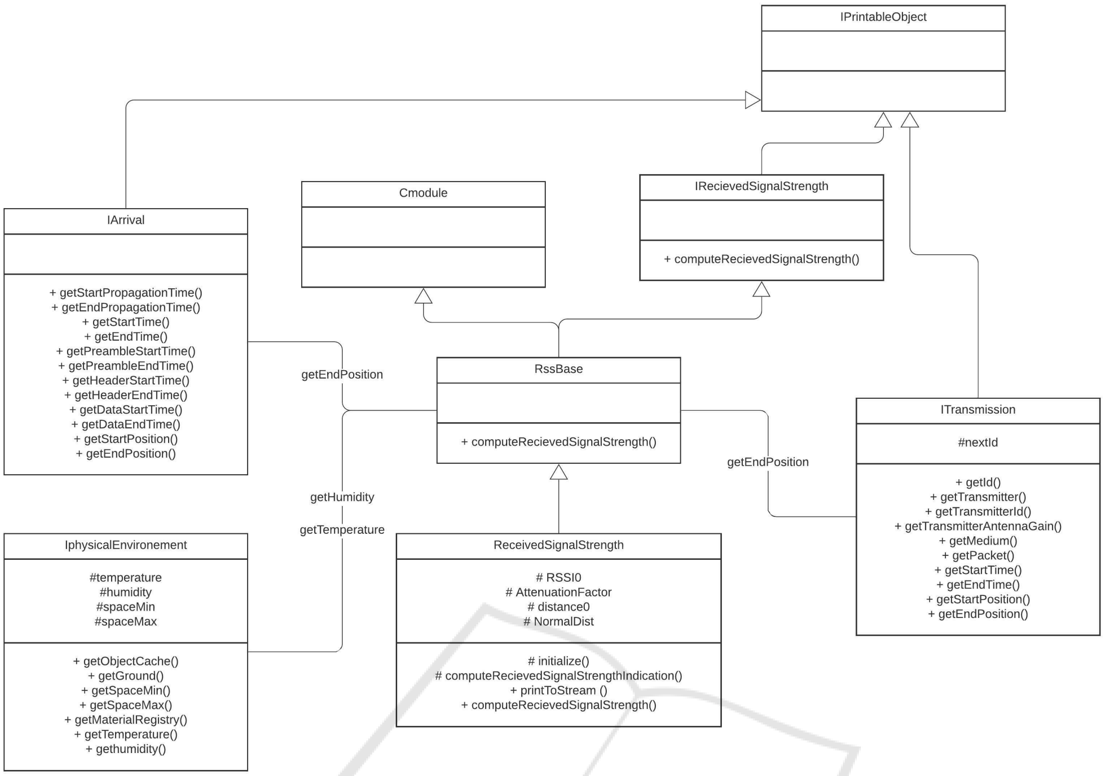


Figure 6: UML class diagram.



The UML class diagram in Fig. 6 can resume and clarify the implemented RSSI module.

After finishing with the implementation of the RSSI module, a test phase will take place, the configuration is involved in the INI file of the simulation the RSS-based location default variables are taken from the Location Estimation Algorithm Based on RSSI Vector Similarity Degree (Fengjun Shang, 2014) study and the CC1101 characteristics.

Fig. 7 shows the simulation results after integrating the RSSI module. The humidity was 40RH% and the temperature is 30°C.

In the first step, we compile the impact of temperature on the RSSI, the RSSI0 is taken from the equation 4 of the temperature and the values are compared to the real experiment results in the table 1. The results are almost the same.

Table 1: Variation of RSSI according to temperature in Omnet++ Simulator.

| Temperature(°C) | 5 | 30 |
|---|---|---|
| RSSI in Omnet++(dBm) | -68.8723 | -72.0323 |
| RSSI in Experiment(dBm) | -66 | -74 |

In the next step the simulator tests the humidity impact on the RSSI, the RSSI0 is taken from the equation 5 of the humidity and the values are compared to the real experiment results in the table 2. The simulation results are close to the experiment results.

Table 2: Variation of RSSI according humdity in Omnet++ Simulator.

| Humidity(RH%) | 40 | 70 |
|---|---|---|
| RSSI in Omnet++(dBm) | -67.92 | -72.87 |
| RSSI in Experiment(dBm) | -64 | -68 |

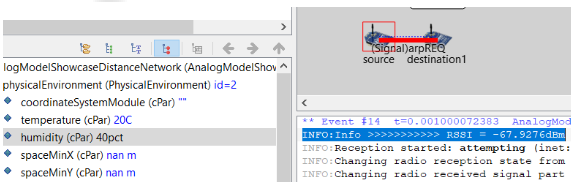


Figure 7: Humidity= 40RH%.

## 5 CONCLUSIONS

The main contribution of this paper is to implement the impact of the humidity and temperature on the RSSI in the Omnet++ simulator. The implementation of the module was based on real experiments. In those studies, the created model was for the CC1101 radio ship transceiver study case.

Experimental measurements were carried out inside a climate test chamber using the Panstamp AVR wireless module and DHT11 temperature and humidity sensors. To comply with this step, several test scenarios were designed to evaluate the measurable criteria. Results have shown that, for wired communication, no correlation was found between temperature, humidity, and RSSI nor LQI.

However, for wireless communication, a strong negative correlation between RSSI and both humidity and temperature was observed. Once the relation between the RSSI, humidity, and temperature was obtained, it was implemented into the Omnet++ simulator to make it valuable for future applications.

The findings presented here can help when designing adaptive RSSI-based applications such as RSSI-based indoor localization. Furthermore, this study can be used to address WSN evaluation, such as scalability and the modeling of mobility, wireless medium, and energy consumption.

This will never end the work in further experiments we can apply the changes on different chips to build other models and blocks in Omnet++, this will large the options for users, and using different choices in the simulator.

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## REFERENCES

Amir Guidaraa, Ghofrane Fersi, F. D. M. B. J. (2018). Impacts of temperature and humidity variations on rssi in indoor wireless sensor networks. In *22nd International Conference on Knowledge-Based and Intelligent Information & Engineering Systems*. IEEE.

Boano, C.A., T. N. V. T. B. J. R. U. (2010). The impact of temperature on outdoor industrial sensornet applications. In *Transactions on Industrial Informatics 6, 451–459*. IEEE.

C. Boano, J. Brown, Z. H. U. R. T. V. (2009). Low-power radio communication in industrial outdoor deployments: The impact of weather conditions and atex-compliance. In *Sensor Applications, Experimentation, and Logistics: First International Conference, SENSAPPEAL*, volume 29, pages 159–176. IEEE.

David Rojas, J. B. (2018). Link quality evaluation of a wireless sensor network in metal marine environments.

Debashis De, Amartya Mukherjee, S. K. N. D. (02 February 2020). Wireless sensor network: Applications, challenges, and algorithms. Springer Tracts in Nature-Inspired Computing book series (STNIC).

Farahani, S. (2008). Zigbee wireless networks and transceivers.

Fengjun Shang, Wen Su, Q. W. H. G. Q. F. (Received 22 April 2014; Revised 2 July 2014; Accepted 10 July 2014; Published 1 September 2014). A location estimation algorithm based on rssi vector similarity degree.

Ilef Ketata, Ahmed Fakhfakh, F. D. (2020). Advanced evaluation platform-based rf attenuators for wireless sensor networks. In *2020 IEEE 6th World Forum on Internet of Things (WF-IoT)*, pages 1–6. IEEE.

Ilef Ketata, Sadok Bdiri, N. D. F. D. (2019). Hardware based simulation platform for wireless sensor networks. In *2019 16th International Multi-Conference on Systems, Signals & Devices (SSD)*, pages 339–344. IEEE.

K. Bannister, G. Giorgetti, S. G. (June 2008). Wireless sensor networking for" hot" applications: Effects of temperature on signal strength, data collection and localization. In *The Fifth Workshop on Embedded Networked Sensors (HotEmNets'08), Charlottesville, Virginia, USA*.

Luomala, J., H. I. (2015). Effects of temperature and humidity on radio signal strength in outdoor wireless sensor networks. In *Computer Science and Information Systems (FedCSIS), 2015 Federated Conference*, pages 1247–1255. IEEE.

Michel Bakni, Luis Manuel, M. C. Y. C. G. T. O. C. (December 2019). Wsn simulators evaluation: An approach focusing on energy awareness.

Miloš Jevtić, Nikola Zogović, G. D. (November 24-26, 2009). Evaluation of wireless sensor network simulators. In *17th Telecommunications forum TELFOR 2009*. IEEE.

Nouha Baccour, Anis Koubâa, C. N. H. F. M. A. H. Y. M. A. Z. C. A. B. K. R. D. P. T. V. M. (2013). Radio link quality estimation in low-power wireless networks. SpringerBriefs in Electrical and Computer Engineering book series (BRIEFSELECTRIC).

Org, O. (July,2021). Omnetpp org.