International Journal of Bioelectronics
ISSN 2448-7732

Study of Power of Received Signal Strength Indicator (RSSI) for the distance between nodes, based on Freakduino for Wireless Sensor Networks (WSN)

Estudio de Potencia del Indicador de Fuerza de la Señal Recibida (IFSR) para la distancia entre nodos, basado en Freakduino para Redes Inalámbricas de Sensores (RIS)

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ABSTRACT

Wireless Sensor Networks are composed of autonomous electronic nodes that are able to obtain data from different types of sensors and transmit the information to others. This research presents the study of RSSI power vs the coverage distance of a Freakduino board, in an area with obstacles. Three types of sensors were used at different distances between nodes to test their performance, with a receiver and transmitter nodes, its programs was developed on Arduino free software, to get a view of the behavior of the node. The results obtained show that it is possible to increase the power of the RSSI signal by programming the parameters almost at double, but, it was not possible to obtain a range higher than180 meters.

Keywords: Wireless Sensor Networks, **R**eceived Signal Strength Indicator (RSSI), **F**reakduino, **N**odes, **D**istance.

RESUMEN

Las Redes inalámbricas de sensores se componen de nodos electrónicos autónomos que son capaces de obtener datos de distintos tipos de sensores y transmitir la información a otros nodos. Esta investigación presenta el estudio de la potencia RSSI vs la distancia de cobertura de la tarjeta Freakduino, en una zona con obstáculos. Se utilizaron tres tipos de sensores a diferentes distancias entre nodos para probar su desempeño, con un nodo receptor y otro transmisor, cuyos programas fueron desarrollados en base al software Arduino de acceso libre, para obtener una visión del comportamiento del nodo. Los resultados obtenidos muestran que es posible incrementar la potencia de la señal RSSI mediante la programación de los parámetros casi al doble; sin embargo, no se logró obtener un rango de distancia que sobrepasara los 180 metros.

Palabras clave: Red Inalámbrica de Sensores, **I**ndicador de Fuerza de la Señal Recibida (IFSR), **F**reakduino, **N**odos, **D**istancia.

Introduction

Nowadays, wireless sensor networks (WSN) have reached a technological and application development that covers many areas of science. Compared to wired networks, they have advantages such as reduced size, easy installation and low cost. At this time, there are many areas where WSN can be implemented: from military applications to medicine and environmental monitoring (Benkic, 2008). A WSN is an integration of electronic devices that monitor physical variables implemented with different types of topologies and protocols, focused on a field or area of interest. For example, greenhouses and crops with agronomical applications, or monitoring of vital signs in medicine. Figure 1shown an example of a WSN basic structure.

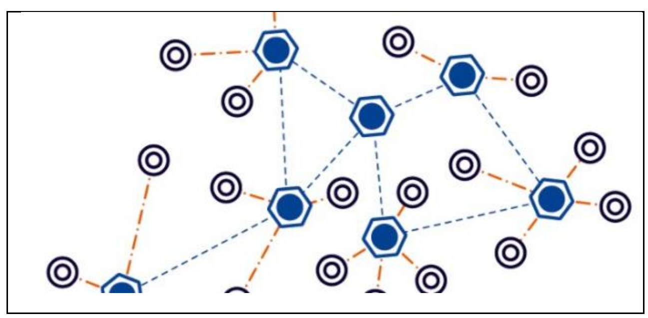

Figure 1. Wireless Sensor Networks, hexagons represents nodes and circles represents sensors.

These devices are also known as nodes (or motes), and can be composed of different modules: Sensor module that is responsible of acquire physical variables. Wireless communication module for transmitting information, radio frequency (RF) is one of the most used, data processing module that interprets information and

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takes decisions, module for storing data and a module of energy supply that feeds the node and makes it independent.

Usually, the nodes used in the WSN are data acquisition cards, (Data Acquisition System or DAQ) that act as an interface between a computer and physical signals. The information acquired by the sensor is passed to the DAQ, which is responsible for transforming the codes of the real world to digital codes, as an interpreter that translates from one language to another (JMIndustrial, 2018).

The energy consumption of the nodes is a crucial point in the design and implementation of the same. It is convenient that the node be autonomous and must be installed in a strategic zone where the variables of interest are monitored. The optimization of power consumption is a key point in the energy saving and efficiency of the node, which can be achieved by programming a sleep-wake cycles in the node or modifying the parameters of the board with which one works.

Freakduino as a node for WSN

There are many technologies oriented to the use of WSN. One of them is the Freakduino-900MHz board from FreakLabs (FreakLabs, 2018). It is designed for rapid prototyping, experienced and development of low cost wireless designs, also allows to acquire the basic knowledge of wireless sensor networks without having to deal with very complex tools, protocols and advanced software. It combines the ease of the Arduino programming environment, the compatibility with a large number of peripherals and integrates radio networks for a wireless prototyping system. The Freakduino board also has special features that make it ideal for use as a node, among these features is the fact of incorporate a battery regulator circuit, to alternate between two operating voltages 3.3V and 5V, external antenna connector and module CC1190 for high performance wireless applications (Texas Instruments).

Nodes and its relationship with RSSI Power

Localization methods based on the power of the received signal (RSSI) are the most frequently used in WSN and Wi-Fi technologies (Meza, 2007). In the data acquisition boards, a signal is used from the sending node to the receiving node with an RSSI indicator to estimate the distance between them. One of the advantages of using this method is the fact that the RSSI measurements are obtained directly by the radio modules without the need for additional components.

The dBm is a unit of power expressed in decibels (dB) relative to a milliwatt (mW) used to express the absolute power measurement being dimensionless unit whose objective is the quantification of data (Bigelow, 1991). The value of the RSSI force indicator can be described as follows:

• Weak and noisy signal will return a low level of RSSI.

• Strong signal and no noise will return a high level of RSSI.

Determining the parameter configuration for the node

The value of the RSSI indicator will be an integer between 0 to 84, which is the maximum radius that can be handled by Freaklabs without becoming saturated. To calculate the dB of the RSSI value, the following formula is used:

$$P(dBm) = (RSSI\ Base\ value) + (1.03 \times RSSI\ Level) \qquad (1)$$

Where:

P[dBm] is the power in dBm units

RSSI Base value equals -98 (OQPSK modulation at 250 kbps)

RSSI Level is the level obtained in the board

The base value is obtained from the manufacturer's official page and is the parameter used for the node configuration by programming the corresponding command in the library and with this, the maximum RSSI value in dBm would be -11.48 dBm and -96.97 dBm. This parameter is the same for Freakduino boards V2.1a and V3.0a.

The library developed by Freaklabs for the programming and configuration of the Freakduino board is a file called 'chibiUsrCfg.h' which has different functions that allows to changes the configuration to adapt the application where the board is implemented. Freakduino handles the changes in its configuration allowed by the IEEE 802.15.4 protocol. The Freakduino-900 V2.1a and V3.0a boards work with 900 MHz frequency and 10 channels.

For the configuration of the sensor nodes, the following parameters were programmed:

Network address

- Address of Coordinator node: 0x0001
- Address of Sensor 1 node: 0x0003
- Address of Sensor 2 node: 0x0005

Personal Area Network (PAN) ID

16-bit identifier to select the PAN working network. All nodes must be configured with the same PAN ID for a right communication between the devices. It was established with 0x1234 address.

Node Identifier

String of 20 characters to identify the node in the network. Not was implemented.

Channel

Channel 10, in the range of 868 MHz to 915 MHz, was selected.

Maximum Data Payload

Determine the longest size than can be transmitted in a single frame. The range was form 1 to 116 bits. MaxPayLoad: 100.

Materials and methods

The next figure (figure 2) presents the methodology used to develop the project.

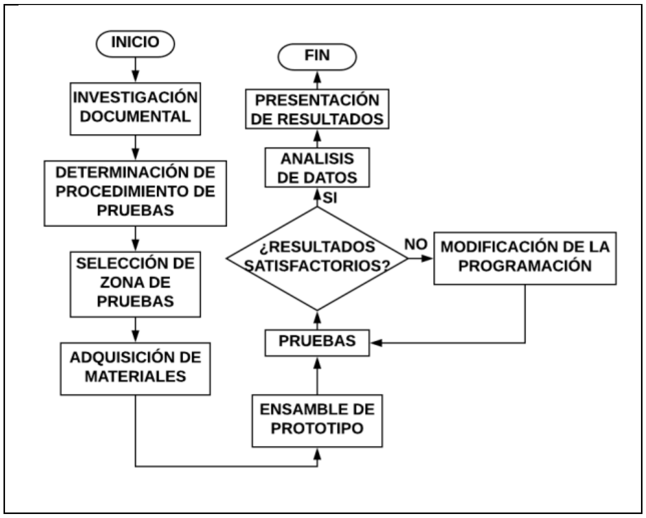

Figure 2. Methodology used in the project.
Source: Authors

Tests of distance with respect to the power of RSSI signal

To measure the propagation of the signal, an external scenario with obstacles was selected as an area of study; the Venustiano Carranza Forest located in Calzada Cuauhtémoc and Av. Juárez in City of Torreón, Coahuila. Whose location coordinates are 25 ° 32.4708'N 103 ° 26.0155'W. In Figure 3, the position of the nodes and the distance with respect to the receiver node.

Figure 3. Location of the nodes.
Source: Authors

Tests were developed with two types of boards: Freakduino 900 MHz v2.1a as receiver node and Freakduino 900 MHz v3.0a as transmitter. In both cases, Atmega328P microcontroller and AT86RF230 wireless integrated circuits allows radio communication and its signal strength goes from 84 (-11.48dBm) to 0 (-96.97dBm) with an accuracy of +/- 5 dB. We also used a Dell computer with an AMD A10-8700P Radeon R6 4-core and Windows 10 64-bit operating system for the development of programming and visualization of the results on the serial monitor (figure 4).

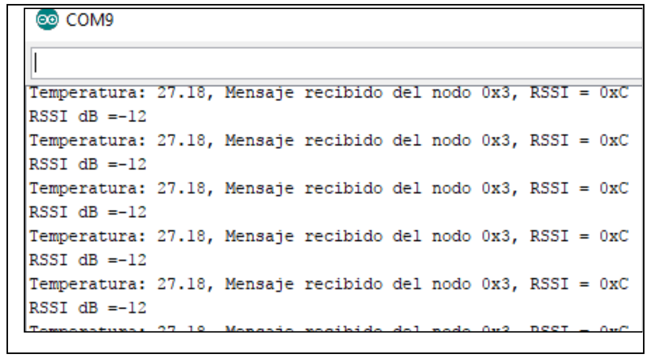

Figure 4. Readings from the LM35dz sensor in serial mode.
Source: Authors

The program designed for the boards was developed in Arduino development environment, considering that it is wanted to observe in the receiving board the power of the RSSI signal, the address of the transmitting node and the sensor readings. To measure the RSSI power with respect to distance, geo-positioning applications with smartphones were used, which allowed using coordinates to take a reading in meters from the receiving node to the transmitting node at different locations.

Through the transmitting node, the data acquisition of the sensors is made, the address of the receiving node and the transmitting node it is programmed. The distances selected for the tests of the three phases are 0, 30, 50, 100, 120, 150, 180 and 200 meters.

It was decided to use 3 different types of sensors: the LM35dz (environmental temperature), the DHT11 (environmental temperature and relative humidity) and FC-28 (relative humidity) [7-9]. This, in order to program many ways to send data sensor wirelessly. The results obtained from RSSI are given more relevance with respect to distance.

Tests developed

Distance test with respect to the power of RSSI signal with temperature sensor

In the first test, the parameters of the standard library of the board and a LM35dz sensor were used to measure the environmental temperature. The current average temperature was 27 °C, being the start time of tests at 12:00 pm, wind at 0 km/hr, relative humidity 18%.

The results of the first test are presented in Table 1. In some of the distances, the temperature readings show slight variations due to the shade of the trees where the node was located.

Table 1. Result of the test with temperature sensor LM35dz

FECHA Y HORA	DIR. NODO	SENSOR DE T.	DISTANCIA	RSSI
vie_30/09/2017 HORA:12:00:00	0X3	25.27	0	84
vie_30/09/2017 HORA:13:07:01	0x3	26.7	30	26
vie_30/09/2017 HORA:12:50:02	0X3	27.18	50	7
vie_30/09/2017 HORA:12:52:00	0X3	27.18	100	12
vie_30/09/2017 HORA:12:53:00	0X3	27.17	120	11
vie_30/09/2017 HORA:12:56:04	0X3	27.66	150	4
vie_30/09/2017 HORA:12:58:25	0x3	27.71	180	3
vie_30/09/2017 HORA:13:00:01	0X3	25.75	200	1

Source: Authors

In Figure 5, the graph of RSSI vs distance is presented, the maximum value was 84 at a distance of 0 mts. between nodes and the minimum was I at a distance of 200 mts. The intermediate values present variations, probably due to the obstacles, however; it can be considered that the readings obtained with the temperature sensor are reliable.

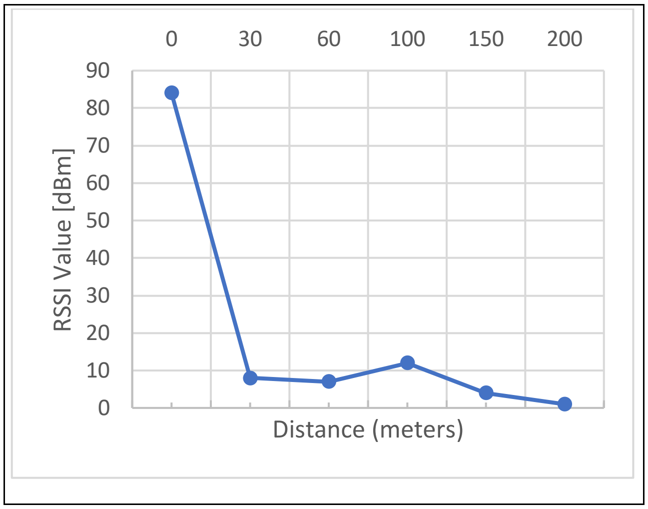

Figure 5. RSSI vs Distance (LM35dz sensor)
Source: Authors

In the following tests, slight modifications were made to try to increase RSSI Power.

Distance test considering power of RSSI signal with DHT11.

In the second test, the predicted maximum temperature of 33°C is taken as reference. Starting the test at 11:19 am, with a wind speed of 11.1 km/hr, and relative humidity of 14.8%. The DHT11 sensor was used. The figure 6 shows the architecture developed in this test.

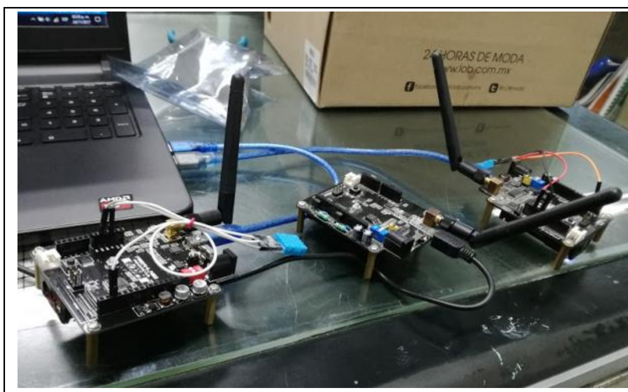

Figure 6. Arduino board with DHT11 sensor
Source: Authors

The results of second test (shown in Table 2) show a similar behavior to the first one. The temperature and humidity sensor also maintained reliable readings at all times. Temperature variations are due to the same cause and humidity due to the fact that different areas of the forest had been irrigated.

Table 2. RSSI tests with DHT11

FECHA Y HORA	DIR. NODO	SENSOR DE H.	SENSOR DE T.	DISTANCIA	RSSI
mar_7/11/2017 HORA:11:19:00	0x3	20%	27.00	0	84
mar_7/11/2017 HORA:11:28:00	0x3	14%	27.00	30	22
mar_7/11/2017 HORA:11:43:00	0x3	8%	33.00	50	15
mar_7/11/2017 HORA:11:52:00	0x3	11%	30.00	100	19
mar_7/11/2017 HORA:11:52:00	0x3	11%	30.00	120	17
mar_7/11/2017 HORA:13:19:00	0x3	13%	30.00	150	12
mar_7/11/2017 HORA:13:26:00	0x3	10%	30.00	180	7
mar_7/11/2017 HORA:13:27:00	0x3	10%	30.00	200	6

Source: Authors

Figure 7 presents the graph of RSSI vs distance. The maximum value was 84 at a distance of 0 meters between nodes and the minimum was 6 at 200 m distance. The intermediate values present variations, probably due to obstacles.

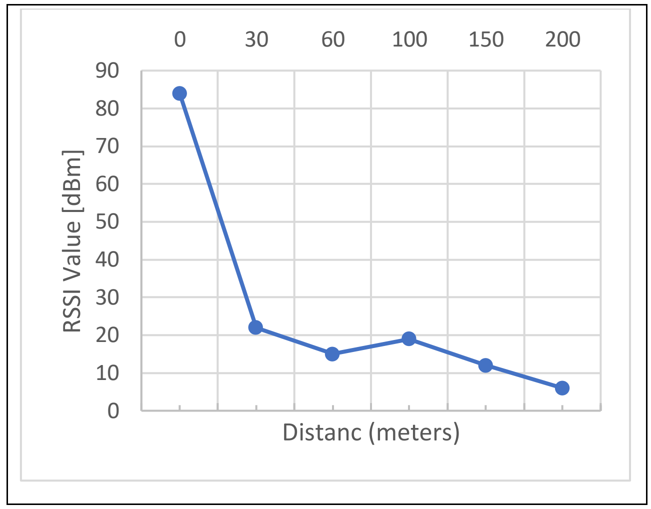

Figure 7. RSSI vs Distance (DHT11 sensor)
Source: Authors

Distance test considering power of RSSI signal with Relative Humidity sensor.

In the third test, the current temperature of 18°C is acquired. Test start at 1:05 pm, wind speed of 13 km/h, average relative humidity of the day was 43.6%. An FC-28 humidity sensor was used. In addition, an increase in resolution was contemplated: from 10-bit Freakduino board to 12-bits ADC MCP3208.

During stage three, modulation parameters were modified through the library of the Freakduino board (Figure 8), defining the direct command in the node program: CHB_900_MHz_INIT_MODE_OQPSK_SIN_1000, to see if there was any increase in the coverage distance. The use of a two-phase phase shift modulation (BPSK) was investigated in the official website in order to increase the range of the distance, with the only drawback being the speed with which the data is transferred, so it was decided to continue using Quadrature staggered phase shift modulations (OQSPK).

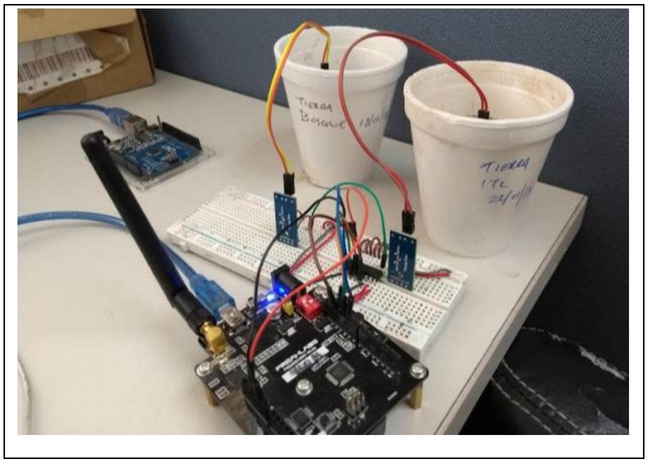

Figure 8. Arduino board v3.0 with ADC MCP328 and FC-28 sensor
Source: Authors

The results was shown in Table 3, RSSI increases significantly with respect to the first two tests. Maintaining, as in the previous ones, stable sensor readings.

Table 3. RSSI tests with relative humidity sensor FC-28

FECHA Y HORA	DIR. NODO	SENSOR DE H.	DISTANCIA	RSSI
mie_24/1/2018 HORA:13:5:52	0X5	39%	0	84
mie_24/1/2018 HORA:13:19:34	0X5	39%	30	36
mie_24/1/2018 HORA:13:21:59	0X5	39%	50	31
mie_24/1/2018 HORA:13:25:37	0X5	40%	100	27
mie_24/1/2018 HORA:13:28:27	0X5	40%	120	28
mie_24/1/2018 HORA:13:58:43	0X5	39%	150	29
mie_24/1/2018 HORA:13:39:26	0X5	40%	180	27

Source: Authors

With the modification of the configurations of the libraries, a considerable increase in the RSSI value was achieved increasing almost twice its power, and reducing the variations; however, it was not possible to obtain a distance range superior of 180 meters (Figure 9).

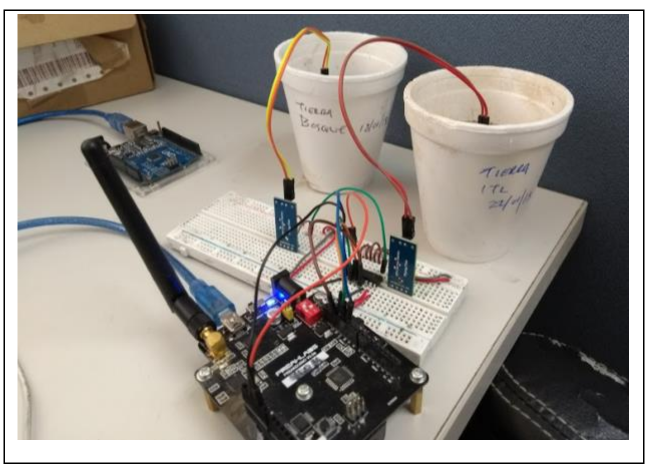

Figure 9. RSSI vs Distance, using a FC-28 sensor.
Source: Authors

Results and Discussion

Figure 10 shows the comparison of RSSI power vs distance selected for the 3 results obtained in the tests.

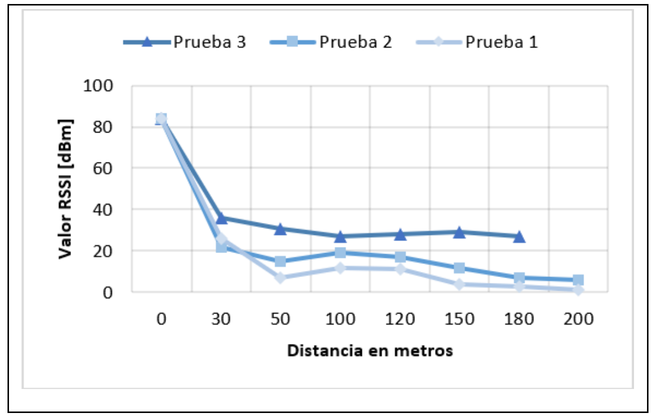

Figure 10. RSSI vs Distance, considering three results obtained.
Source: Authors

As can be seen, there was a considerable increase in RSSI power when testing different types of configurations in the boards, having to sacrifice a range obtained of 200 meters, which implied some lost of information and delays at the time of data reception.

Conclusions

Based on previous research developed by Srinivasan (2006), it can be affirmed that the RSSI value does not have strong variations if there are ideal factors such as the fact that there is no humidity and water.

It can be concluded that it is possible to increase the power of the RSSI signal by programming the parameters of the Freakduino board libraries, but with a slight decrease in the distance coverage range. Depending on the type of application, it can be an advantage to have a power signal that is capable of crossing obstacles if the strategic distance is adjusted to the distances studied.

The Venustiano Carranza forest is an ideal area for tests with obstacles, but there are many Wi-Fi signals that can interfere with the transmission of data.

Acknowledgements

We thank Tecnológico Nacional de México/Instituto Tecnológico de la Laguna (TECNM-ITLaguna) and Consejo Nacional de Ciencia y Tecnología (CONACYT) for the facilities and support provided for the development of this study.

References

Benkic, K., Malajner, M., Planinsic, P. and Cucej, Z. (2008). *Using RSSI value for distance estimation in wireless sensor networks based on ZigBee*. Technical report, IWSSIP 2008.

Bigelow, S. (1991). *Understanding telephone electronics*. Indianapolis, IN: SAMS.

FreakLabs. Freakduino 900 MHz Wireless Arduino Compatible Board, v3.0a [FREAKDUINO CHIBI, Open Source Wireless Sensor Networks. (2018). Available: http://www.freaklabsstore.com/index.php?main_page=product_info&products_id=187 [Accessed may 6, 2017]

JMIndustrial. (2018). Data acquisition boards. Available: https://www.jmi.com.mx/tarjetas-de-adquisicion-de-datos.html [Accessed march 8, 2018]

Mesa López-Colmenar, J., Castañeda Barrena, R. and Villar Angulo, L. (2007). *Experiencia de innovación universitaria*. Universidad de Sevilla, Instituto de Ciencias de la Educación. Sevilla, España.

Srinivasan, K. and Levis,P. (2006). *RSSI Is UnderAppreciated*. Proceedings of the Third Workshop on EmNets 2006.

Texas Instruments. CC1190 DataSheet. Available: http://www.ti.com/product/CC1190 [Accessed march 3, 2018]