Reconfigurable and Long-Range Wireless Sensor Node for Long Time Operation

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Abstract. This paper presents a low-power wireless sensor node platform with long-range communication capabilities based on LoRa technology. A frequency reconfigurable antenna is integrated to compensate effects from the environment. The platform integrates an accelerometer and a temperature sensor and it can monitor and transmit the device activity and temperature during more than 7 years.

Keywords: Wireless sensor network · Reconfigurable antenna · Low-power electronics

1 Introduction

During last decades, a large effort has been devoted to provide wireless connectivity to any type of object. Several disruptive technologies as Low-Power Wireless Area Network (LP-WAN) and ultra-low power electronics are now giving the possibility to connect almost any object almost anywhere [1]. The design of Wireless Sensor Networks (WSNs) for long time operation is very challenging. Power consumption has to be optimized on the radiofrequency, sensing and digital parts [6,7]. In literature, ZigBee and Bluetooth technologies have been mainly used because of the easy integration and wide availability [2,3]. However, wireless communication range is usually limited due to the weak propagation capabilities at 2.4 GHz. Recently, several long-range and low power wireless technologies have been proposed, mainly based on sub-GHz bands, where better propagation characteristics can be found [4]. One of the main issues for miniaturization of sub-GHz communication systems concerns the miniaturization of the antenna. The reduction of the antenna size causes the decrease of the radiation efficiency and the increase of the sensibility to the environment [5].

WSN nodes are usually placed in a-priori unknown environments and therefore smart systems with the capability to adapt to the context is strongly desired. Reconfigurability on the antenna directivity has already been proposed to improve WSN network efficiency [8]. However, this technique cannot compensate the close effect of the environment on the antenna. Proximity effects on

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antennas have been studied for both dielectric and metallic environments. For magnetic antennas, like in RFID applications, the metallic environment causes the frequency resonance to shift towards higher frequency [10]. On the other hand, metallic sections can also be used as a technique to miniaturize the size of antennas. Metallic planes performs a capacitance loading of the antenna so that the frequency resonance is shifted toward lower frequencies [11–13]. Examples of capacitance loading of inverted-F antennas (IFAs) and Planar Inverted-F antennas (PIFAs) using a metallic plane have been proposed in [14,15]. Finally, dielectrics can also cause down-shift in the resonance frequency [9].

A possible solution to compensate the resonance frequency shifting consists in the design of a frequency reconfigurable antenna and successively to re-tune the antenna resonance frequency depending on the close environment of the device.

In this paper, we present a low-power wireless sensor node platform with long-range communication capabilities based on LoRa technology, integrating a reconfigurable antenna to compensate environment effect.

2 Wireless Sensor Node Platform

The proposed WSN platform is based on a LoRa radio system working at 868 MHz, which makes it ideal for low-power small size device trackers. The device fits in a 120 mm long cylinder with a diameter of 20 mm. The system is powered by one AA lithium battery as shown in Fig. 1. In order to provide an optimal radiation performance in any operation context, a reconfigurable antenna has been designed. Thanks to the ability to compensate the environment effect, the WSN platform can be fixed on any type of equipment to efficiently monitor its activity and position.

2.1 Reconfigurable Antenna

In order to compensate the environment effect, a Digital Tunable Capacitor (DTC) connected to the antenna is adopted. We have selected the PE64906 from Peregrine with a capacitance tuning range from 0.9 to 4.6 pF with 32 different states. In order to accurately tune the frequency range of the reconfigurable antenna, an inductor of 15nH is placed in parallel to the DTC (Fig. 1). The typical power consumption of this component is 140 uA for 2.75 V, which is negligible compared to the transceiver power consumption (33 mA for 3.3 V).

LoRa communications are performed at 868 MHz and, considering the small size of the antenna compare to the wavelength, only a reduced bandwidth of 10 MHz can be covered instantaneously (for a reflection coefficient criteria of -6 dB). When the antenna is placed near a dielectric or a metallic part, the resonance frequency is shifted. As an example, for an antenna resonating at 868 MHz in free space, the resonance frequency will shift to 700 MHz when the antenna is placed on a metallic plate. Due to un-matching effect, the transmitted power is reduced by a 12 dB. With the reconfigurable antenna, the frequency shift of the antenna resonance can be compensated by changing the DTC value.

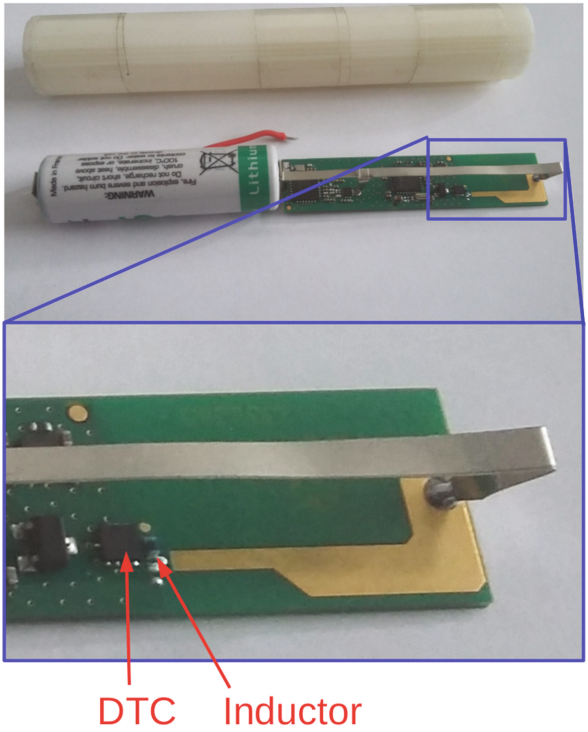

Fig. 1. Picture of the proposed WSN device

2.2 Electronic Components

Long time operation mainly depends on the power consumption of the electronic components. An ultra low power Gecko 32-bit microcontroller (MCU) from Silicon Labs (EFM32G200F64) has been selected. It consumes 2 mA in active mode and only 3 uA in stand-by mode with interrupt inputs enable. The design is based on the LoRa modem using the SX1272 from Semtech with 14 dBm output power. The different power consumptions of the MCU and the transceiver are described in Table 1.

2.3 Sensors

Several sensors are integrated in the device. The most important one is the accelerometer because it will strongly contribute to the power consumption reduction. An ultra-low power 3-axis component from Freescale has been selected (MMA8652FC). The output date rate is set to 12.5 Hz for reducing the power consumption (6.5 uA on 2.5 V). The process of the x, y and z accelerations is described in Fig. 2. The square sum of the accelerations is performed. Then, a highpass filter is used to get rid of the static (gravitational) acceleration value.

Table 1. Power budget of the WSN platform

Components	Current consumption	Duty cycle(%)	Average current
LoRa (active)	38 mA	0.03	10uA
LoRa (sleep)	0.1 uA	99.97	10uA
MCU (stand-by)	3 uA	99	
MCU (active)	2 mA	1	23uA
Accelerometer (LP mode)	6.5 uA	100	6.5uA
DTC	500 uA	0.03	0.15uA
Total		100	40uA

Battery	Power	Autonomy
AA lithium battery	2.6A.h	7.42 years

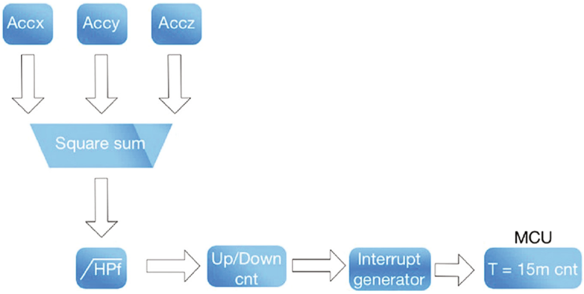

Fig. 2. Accelerometer processing

From this result, a counter is incremented when the output value of the HP filter is higher than a threshold. For a determined period of time (15 min for our model), we count the number of detected accelerations. Since the firmware of the WSN platform is optimized to make as less wireless LoRa uplinks as possible, the system only send an uplink with the count number of detected accelerations every 15 min (if some activity has been detected). The MCU also integrates a temperature sensor.

2.4 Power Budget

Based on a representative scenario, the average power consumption of the device can be extracted from Table 1. The WNS is transmitting each hour with no activity or each 15mn in case of detected activity. The average duration for a LoRa communication can be estimated to 300 ms. Based on a lithium AA battery, an autonomy larger than 7 years can be expected. This calculation do not include the self-discharge of such a battery and the influence of the temperature. As it can be observed from the average current distribution in Fig. 3, most of the power consumption is due to the MCU, and the accelerometer and communication part are consuming almost a quarter of the whole power. It can be also noticed that the power consumption of the DTC, for adding the antenna reconfigurability, is negligible in the overall power budget.

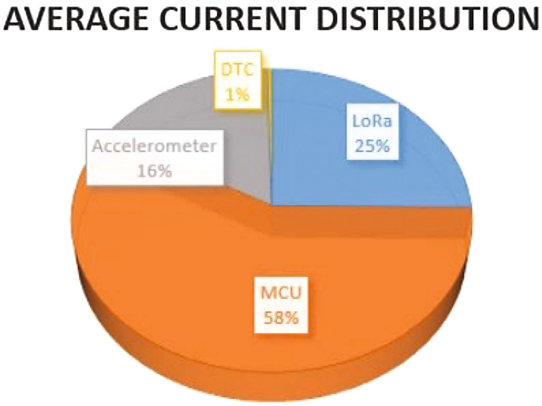

Fig. 3. Average current distribution in a standard scenario

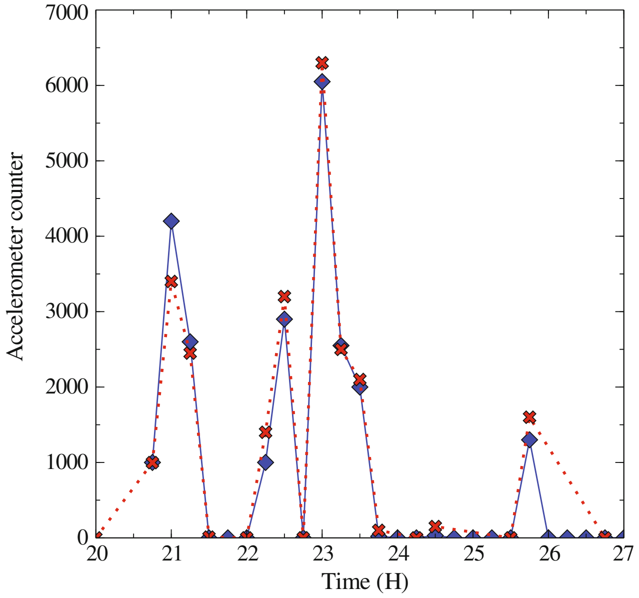

Fig. 4. Comparison between a reference accelerometer (blue) and the device (red) fixed on the same tool. (Color figure online)

3 In-Field Sensing Testing

The first presented test is the comparison between a reference accelerometer and the WSN platform placed on the same object. The result presented in Fig. 4 shows a good agreement between the activity monitored with the reference accelerometer and the WSN node.

The second test evaluates the joint use of the accelerometer and the temperature sensor. The temperature sensor from the MCU is used for the monitoring. The WSN platform has been placed in a tree during 10 days, transmitting temperature and activity detected every 15 min. The results are presented in Fig. 5. The test had been started on July 7, 2016. As expected, the temperature curve exhibits a periodic trend that corresponds to the day/night cycle. The activity counter do not report any accelerations until the 6th day (corresponding to 150 h), which was particularly windy.

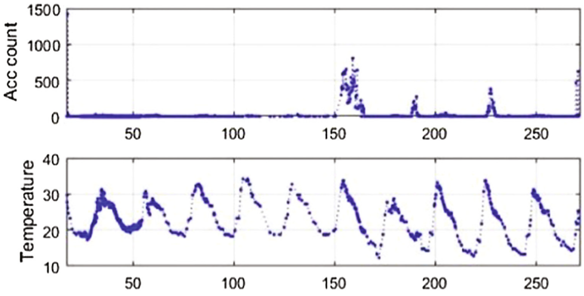

Fig. 5. Activity and temperature monitored on the WSN platform during 10 days

4 Conclusion

This paper presents a reconfigurable wireless sensor platform for long-time and long-range applications. In-field tests have confirmed a communication range in open environment up to 10 km. Autonomy up to 7 years is expected.

References

1. Lazarescu, M.T.: Design of a WSN platform for long-term environmental monitoring for IoT applications. IEEE J. Emerg. Sel. Top. Circ. Syst. **3**(1), 45–54 (2013)
2. Nair, K., et al.: Optimizing power consumption in iot based wireless sensor networks using bluetooth low energy. In: 2015 International Conference on Green Computing and Internet of Things (ICGCIoT), pp. 589–593, Noida (2015)
3. Chou, J.C., et al.: Wireless sensing system for flexible arrayed potentiometric sensor based on XBee module. IEEE Sens. J. **16**(14), 5588–5595 (2016)

4. Petajajarvi, J., Mikhaylov, K., Roivainen, A., Hanninen, T., Pettissalo, M.: On the coverage of LPWANs: range evaluation and channel attenuation model for LoRa technology, In: 2015 14th International Conference on ITS Telecommunications (ITST), pp. 55–59, December 2015
5. Ferrero, F., Lizzi, L., Danchesi, C., Boudaud, S.,: Environmental sensitivity of miniature antennas for IoT devices. In: IEEE APS 2016 Proceedings, Fajardo, Porto Rico, July 2016
6. Dietrich, I., DresslerSmith, F.: On the lifetime of wireless sensor networks. ACM Trans. Sens. Netw. **5**(1), 5:15:39 (2009)
7. Yang, J., Li, X.: Design and implementation of low-power wireless sensor networks for environmental monitoring in wireless communications. In: IEEE International Conference on Networking and Information Security, pp. 593–597 June 2010
8. Le, T.N., et al.: Improving energy efficiency of mobile WSN using reconfigurable directional antennas. IEEE Commun. Lett. **20**(6), 1243–1246 (2016)
9. Babar, A.A., Ukkonen, L., Elsherbeni, A.Z., Sydnheimo, L.: Wall-proximity effects on the performance of small antennas for UHF wireless applications [wireless corner]. IEEE Antennas Propag. Mag. **53**(6), 190–203 (2011)
10. Qing, X., Chen, Z.N.: Proximity effects of metallic environments on high frequency RFID reader antenna. IEEE Trans. Antennas Propag. **55**(11), 3105–3111 (2007)
11. Seeley, E., Burns, J., Welton, K.: Cap-loaded folded antenna. IRE Int. Convention Rec. **6**, 133–138 (1958)
12. Gangi, A., Sensiper, S., Dunn, G.: The characteristics of electrically short, umbrella top-loaded antennas. IEEE Trans. Antennas Propag. **13**(6), 864–871 (1965)
13. Francavilla, L.A., McLean, J.S., Foltz, H.D., Crook, G.E.: Mode-matching analysis of top-hat monopole antennas loaded with radially layered dielectric. IEEE Trans. Antennas Propag. **47**(1), 179–185 (1999)
14. Rowell, C.R., Murch, R.D.: A capacitively loaded PIFA for compact mobile telephone handsets. IEEE Trans. Antennas Propag. **45**(5), 837–842 (1997)
15. Loizou, L., Buckley, J., Belcastro, M., Barton, J., O'Flynn, B., O'Mathuna, C.: Miniaturized inverted-f antenna with capacitive loading. In: 7th European Conference on Antennas and Propagation, pp. 3213–3216 (2013)