A Comparative study of wireless modules for energy harvesting based WSN

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ABSTRACT – This paper presents a comparative evaluation of RF ASK 315 MHz, HC-12 433MHz RF UART, and nRF24L01 wireless modules. These modules are potential to be used in wireless sensor node powered by energy harvester. The evaluation will discuss the power consumption, coverage area, transfer rate, and the interfacing type. The experimental outcome revealed that the RF ASK 315 MHz is the most suitable wireless module for WSN due to its low power consumption of 0.3mW, reasonable coverage area of 25meters, relatively good transfer rate for WSN application of 2Kbps, and very simple and easy interface by using a single wire.

1. INTRODUCTION

Wireless Sensor Networks WSNs play a major role in the field of multi-hop wireless networks applications, ranging from structural and human health monitoring, to border security and environmental control [1]. A typical WSN node is consist of four main modules: microcontroller; sensor; wireless; and power. This paper focus on the wireless module, which is the most power hungry among others. The wireless module is responsible for data delivery among the WSN nodes.

Many of the researchers have employed different types of off-the-shelf wireless modules in their proposed architecture for a WSN node. For instance, Murat et.al. [2] utilized a WiFi module in the proposed sensor node prototype for aircraft cabin monitoring. Another researcher proposed a novel prototype of a sensor node based on CSR BlueCore 02 Bluetooth module for wireless transmission [3]. Zigbee module also has been used in the design of a sensor node targeted for forest monitoring application [4]. Some other researchers have gone beyond these by studying the data losses in the WiFi-based sensor nodes [5], radio propagation analysis [6], and energy consumption simulation for the CC2420 radio chip [7].

Motivated by the prior researches where they had used different wireless transmission modules and had successfully characterized some of the modules parameters according to their needs, herein, the power consumption, coverage area, transfer rate, and the interfacing type of the RF ASK 315 MHz, HC-12 433MHz RF UART, and nRF24L01 wireless modules have been specifically investigated. Consequently, this paper provides the WSN designers with reliable data about the wireless modules that is not provided in the manufacturer datasheet.

2. METHODOLOGY

The previously mentioned wireless modules as shown in Figure 1, were chosen based on their small size, low cost, easy to operate via hardware (encoders and decoders ICs) or software (libraries), and have a wide operating voltage range up to 12 V.

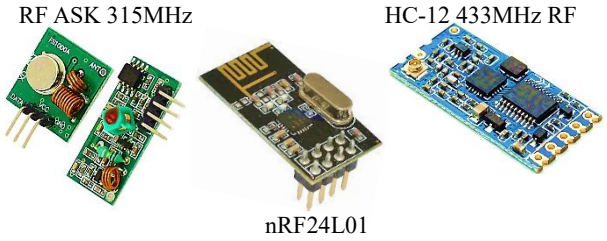

Figure 1 Wireless modules used in this research.

For the evaluation purpose, a measurement circuit consists of low power AVR 8-bit MCU MEGA328P, DUT, two power sources, and two measurement tools is constructed as shown in Figure 2. It is clear from Figure 2 that the DUT has its own variable power supply to easily adjust the supplied voltage to the wireless module without interrupting the MCU. A voltmeter is connected in parallel with the DUT to measure the supplied voltage and an ammeter is connected in series with the DUT in order to measure the drawn current by the module. Therefore, the consumed power can be calculated as $P=I*V$.

3. RESULTS AND DISCUSSION

Since all the three wireless modules are very identical in their relatively small size as shown in Figure 1, so all of them are suitable for small size autonomous sensor node. However, the empirical results shown in Table 1 reveals that the HC-12 433MHz module is the most expensive and very power hungry module, where it consumes 24mW. In another hand, the good feature in this module is it can cover an area of 1 kilometre with 15 Kbps on air transfer rate so it can reduce the number of deployed sensor nodes in the field. This module also required UART to interface with the

Table 1 Wireless modules compression data.

Wireless module	Mini voltage (V)	Mini power (mW)	Idle power (mW)	Coverage area (m)	Interface	Transfer rate (kbps)	Cost
ASK 315MHz	1	0.3	0.00013	25	Single wire	2	Cheapest
HC-12 433MHz	3	24	10.5	1000	UART	15	Expensive
nRF24L01	3.3	0.33	0.0033	10	SPI	1000	Cheap

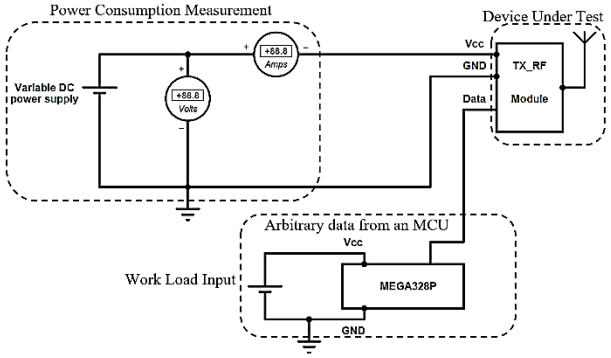

Figure 2 Evaluation experiment set-up.

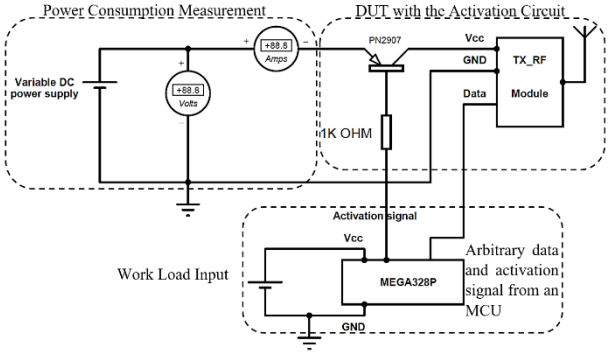

Figure 3 Proposed switching circuit.

MCU, where it considered as an extra load on the MCU. The ASK 315MHz and the nRF24L01 wireless modules are almost similar with slight differences. The nRF24L01 consumes 0.01mW higher than the ASK, however, the ASK covers larger area with 2 Kbps transfer rate than the nRF. The 2 Kbps transfer rate is considered more than enough for the limited amount of data in the WSN applications. Another feature in the ASK 315MHz module is that it supports simple single wire interface with the MCU, which make it easy to be used with any MCU, comparing to the SPI or the UART interface where they increase the overall MCU power consumption. This features make the ASK 315MHz module suitable for low power sensor nodes applications especially for energy harvesting. A very cheap module is another point goes to the ASK 315MHz since it is the cheapest module among the others, where it can cut-off the sensor node manufacturing cost.

In addition, it was found that when the wireless module is idling (especially for the non-programmable modules); it still consumed some noticeable power as clear in Table 1. Any power consumption during the sleep/idle period, is considered as a wasted energy. A solution for this issue is proposed in Figure 3, where module is isolated from the power supply by a switch circuit during the sleep/idle period. Utilizing this circuit can make the node system operates at lowest power consumption during the sleep period.

4. CONCLUSION

Comparative evaluation of three wireless modules has been presented. The evaluation includes the electrical parameters that are not found in the manufacturer datasheet, like less amount of voltage and minimum power required to power up the modules, also proposed circuit to further reduce the modules power during the sleep mode. The evaluation discussed the power consumption, coverage area, transfer rate, and the interface type. The experimental showed that the RF ASK 315 MHz is the most suitable wireless module for WSN due to its low power consumption of 0.3mW, reasonable coverage area of 25meters, relatively good transfer rate for WSN application of 2Kbps, and very simple and easy to interface by using a single wire. Also, a switching circuit is proposed to fix the idle power consumption issue.

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