Review Article

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Ultra-Low Power IoT Solution based on WSSN for Monitoring Infrastructures

Luís Miguel Pires[1]*

[1]*Director CTeSP Automation and Robotics Superior School of Engineering and Technologies (EET), Polytechnic Institute of Lusofonia, Lisbon, Portugal*

***Corresponding Author**
Luís Miguel Pires, Director CTeSP Automation and Robotics Superior School of Engineering and Technologies (EET), Polytechnic Institute of Lusofonia, Lisbon, Portugal.

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1. Introduction

In recent years, one of the emerging technologies that have had big impact on the field of research is Wireless Smart Sensors Networks (WSSN) given its diversity of features and applications. The accelerating growth in IoT for data communication, for sensing and monitoring applications (ranging from biomedical to environmental targets) has originated a high demand not only for low-power autonomous devices but also for ultra- low cost combining single chip radio with baseband signal and digital data processing [1]. Target applications, such as Smart Grids, Cyber-Physical Systems, Body Area Networks, Internet of Things (IoT) and high-density environmental sensing networks, will be massively available if it is removed the requirement of explicit human action for energy recharge. A third concern for the deployment of large numbers wireless sensor networks is the cost of each individual remote device.

Present day infrastructure such bridges, buildings, roads and tunnels can use WSSN to test for structural fatigue caused by high vibrations, fire, flood, ice, etc. Patterns of these conditions can be monitored by using smart sensor nodes that transmit information to a Base Station (BS). This allows engineers to analyze structural damage and prevent future destruction. These WSSNs will be need for civilian and military use for extended time periods, requiring the system to use ultra-low power consumption, and to harvest energy from the surrounding environment. Several challenges were presented including o low signal-to-noise ratio and low maintenance. Surrounding environment conditions like noise and interference can lower efficiency of low power signals. The WSSN was designed to withstand all forms of environmental conditions and harvest energy from the environment so that the sensors need little to no maintenance. Access to the data collected by the WSSN was also included in the design. The Wi-Fi network is the best solution because is a TCP/IP network and with a good coverage compare to other wireless networks. BS module includes a Raspberry Pi 3 (with Wi-Fi controller in the architecture) with Raspbian OS and Apache Server (webpage to access remotely).

In this paper, we propose a smart IoT node architecture to be applied in WSSN for infrastructure monitoring. In section 2, we explain IoT node architecture. Section 3 is dedicated to overview of components and system functionality. Finally in section 4, we draw the conclusions [2].

2. Smart IoT Node Architecture

WSSN tend to expand exponentially in a way so that these small devices can be easily deployed anywhere and collect any information from the environment. The development of monitoring systems based on miniaturized micro solid state technology allows a large monitoring systems using Micro-Electro-Mechanical Systems (MEMS) sensors which include a type of nano scale electrical, thermal, mechanical, optical or flow, among others [3]. On the other hand, the environmental monitoring is one of the main areas of application of this technology due to its characteristics that allow the measurement of parameters in different environmental settings, such as crop management, protection of forest fires, agriculture, earthquakes, active volcano, it is also possible to use macro- instruments for measuring parameters of large-scale such as landslides, atmospheric meteorology, pollution studies or even for planetary exploration and finally water management [4]. Water management requires massive, low-cost monitoring means coping with differentiated and evolving requirements. IoT is the recognized next step of ubiquitous networking of machines and devices (Cyber-Physical Systems). Smart appliances currently evolve in conjunction with small, lightweight devices which generate completely new requirements for underlying radio communication technology.

Recent technological advances in low power integrated circuits and wireless communications have made available efficient, low cost, low power miniature devices for use in remote sensing applications. The combination of these factors has improved the viability of utilizing a sensor network consisting of a large number of intelligent sensors, enabling the collection, processing, analysis and dissemination of valuable information, gathered in a variety of environments. Sensor data are shared among sensor nodes and sent to a distributed or centralized system for analytics. The components that make up the WSN monitoring network include: sensor node, WSN communication stack, middleware and secure data aggregation. In this work we focusing on WSN hardware. The sensor node is one of the main parts of a WSN. The hardware of a sensor node generally includes: the power, power management module, a sensor, a microcontroller, and a RF transceiver (Wi-Fi transceiver). The power module offers the reliable power needed for the system. The sensor is the bond of a WSN node which can obtain the environmental and equipment status. A sensor is in charge of collecting and transforming the signals, such as light, vibration and chemical signals, into electrical signals and then transferring them to the microcontroller. The microcontroller receives the data from the sensor and processes the data accordingly. The RF module then transfers the data, so that the physical realization of communication can be achieved. It is important that the design of the all parts of a WSN node consider the WSN node features of tiny size and limited power. According the previously paragraphs we developed an architecture to a smart IoT node, Figure 1.

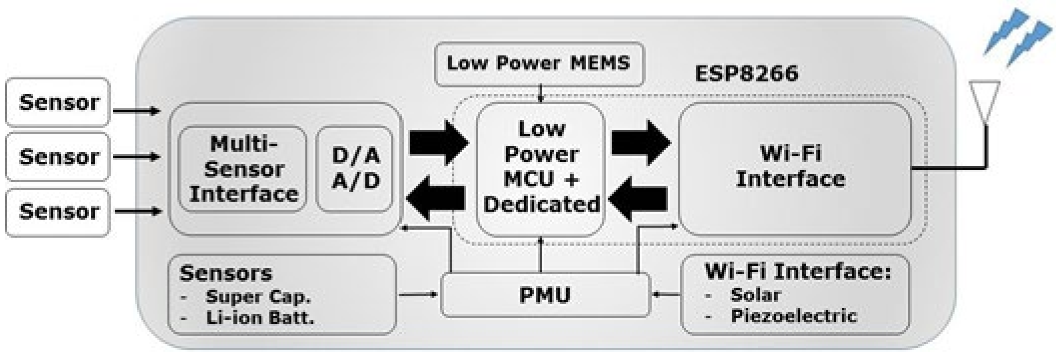

Figure 1: Smart IoT Node Architecture.

This architecture contains 3 parts: Multi-sensor, ESP8266 and Power Management Unit (PMU) [5]. Multi-sensor block incudes: multi-sensor interface, A/D, D/A, signal condition circuits. The ESP8266 block is a low-cost and low-power Wi-Fi chip with full TCP/IP stack and Microcontroller Unit (MCU), dedicated, reprogrammable and reconfigurable.

PMU provides power optimization process, with two approaches, for sensors and for MCU, for sensors: Li-ion batteries and/or super capacitors. For the MCU side, harvesting energy is the best solution, for example: solar or vibration (piezoelectric).

Our approach is to design a low-cost and low-power smart multi-sensor IoT node for WSSN. The system includes a BS: to remotely access (supervising and monitoring all the sensors and processing data from all the sensors and all the nodes. It is possible to include in BS a 4G/3G portable router (using USB interface connected to Raspberry Pi 3) to guarantee a global coverage using cellular/mobile networks.

3. System Design

After complete construction of the project, the node costs is approximately 100 (without sensors) and the BS approximately €70. System architecture is present in Figure 2.

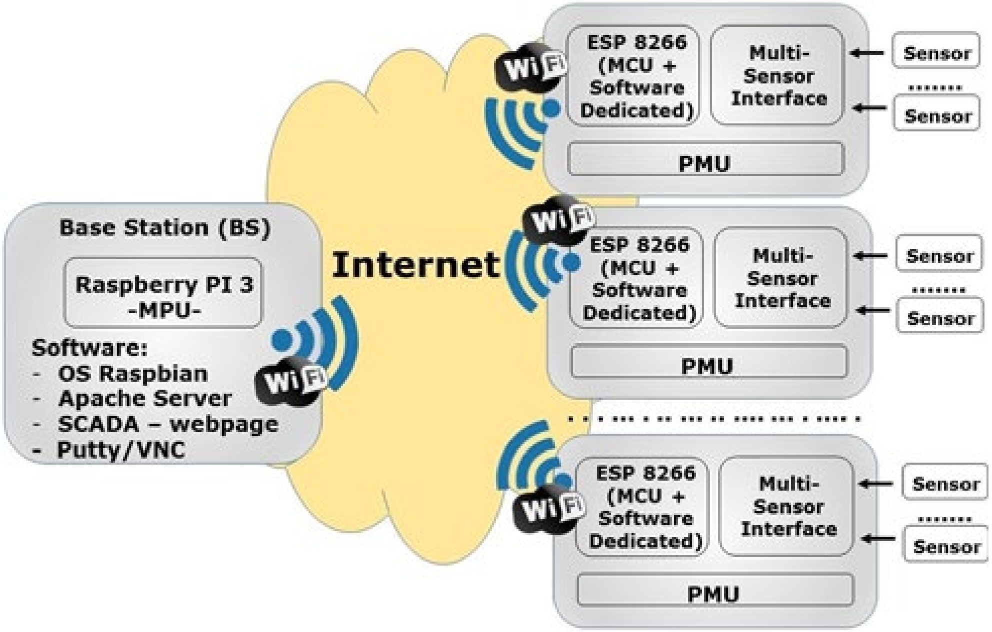

Figure 2: System Architecture.

3.1 Base Station

Base station includes Raspberry Pi 3 [6], the third generation Raspberry Pi. The Raspberry Pi is a series of small single-board computers developed in the United Kingdom by the Raspberry Pi Foundation to promote the teaching of basic computer science in schools and in developing countries. The original model became far more popular than anticipated, selling outside of its target market for uses such as robotics. Peripherals (including keyboards, mice and cases) are not included with the Raspberry Pi. Some accessories however have been included in several official and unofficial bundles. All models feature a Broadcom System on Chip (SoC), which includes an ARM compatible central processing unit (CPU) and an on-chip graphics processing unit (GPU, a VideoCore IV). CPU speed ranges from 700 MHz to 1.2 GHz for the Pi 3 and on board memory range from 256 MB to 1 GB RAM. Secure Digital (SD) cards are used to store the operating system and program memory in either the SDHC or Micro SDHC sizes. Most boards have between one and four USB slots, HDMI and composite video output, and a 3.5 mm phone jack for audio. Lower level output is provided by a number of GPIO pins which support common protocols like I²C. The B-models have an 8P8C Ethernet port and the Pi 3 has on board Wi-Fi 802.11n and Bluetooth. The Foundation provides Raspbian, a Debian-based Linux distribution for download, as well as third party Ubuntu, Windows 10 IoT Core, RISC OS, and specialized media center distributions. It promotes Python and Scratch as the main programming language, with support for many other languages. The default firmware is closed source, while an unofficial open source is available. Raspberry Pi 3, includes:

- 1.2GHz 64-bit quad-core ARMv8 CPU
- 802.11n Wireless LAN
- Bluetooth 4.1
- Bluetooth Low Energy (BLE)
- 1GB RAM
- 4 USB ports
- 40 GPIO pins
- Full HDMI port
- Ethernet port
- Combined 3.5mm audio jack and composite video
- Camera interface (CSI)
- Display interface (DSI)
- Micro SD card slot (now push-pull rather than push-push)
- VideoCore IV 3D graphics core

In the software side, we include Raspian OS (based on Linux), and adding:

- Python 3 (for code developed)
- Apache Server (for remote access and to support SCADA webpage)
- Putty/VNC (for P2P remote access)

3.2 Smart IoT Node

Smart IoT Node includes: ESP8266, multi-sensors and PMU. The ESP8266 WiFi module is a self-contained SoC with integrated TCP/IP protocol stack that can give any microcontroller access to Wi-Fi network. This module is programming in C/C++ for sensors data acquisition and to communicate with WiFi network. This module has a powerful enough on-board processing and storage capability that allows it to be integrated with the sensors and other application specific devices through its GPIOs with minimal development up-front and minimal loading during runtime. Its high degree of on-chip integration allows for minimal external circuitry, including the front-end module, is designed to occupy minimal PCB area.

The ESP8266 support any sensors (analog and digital) powered by 5V or 3.3V. There are a pinout limitation, so it's possible to connect directly (without adding additional circuit interface) 13 digital sensors (directly, Rx/Tx, SPI or I²C) and 1 analog sensor.

PMU is the power management and optimization block which provides power to all the devices included in the node. Li-ion batteries or super capacitor would be used for powered all sensors. The power solution for ESP8266 is using harvesting energy, like piezoelectric (vibration) and voltage panel (solar), in this case we create a charge circuit to powered batteries and super capacitor.

4. Conclusion

We test one node with one accelerometer and one piezoelectric sensor, in an infrastructure with different levels of vibrations. After we adding another node, with another accelerometer and another piezoelectric sensor. In both cases, data was successful transmit to the BS. There are several things that can be improved upon in this system. For example, develop a better webpage (with the SCADA software interface), a variety of sensors can be added to the system such as a water sensor to test for flooding, a barometer to test air pressure, temperature, and altitude, or humidity sensor.

5. References

1. Iniewski, K. (Ed.). (2017). Wireless technologies: circuits, systems, and devices. CRC press.
2. O'Donnell, I. D., & Brodersen, R. W. (2005). An ultra-wideband transceiver architecture for low power, low rate, wireless systems. IEEE Transactions on vehicular technology, 54(5), 1623-1631.
3. Morris, C. J., Stauth, S. A., & Parviz, B. A. (2005). Self-assembly for microscale and nanoscale packaging: Steps toward self-packaging. IEEE Transactions on Advanced Packaging, 28(4), 600-611.
4. Akyildiz, I. F., Su, W., Sankarasubramaniam, Y., & Cayirci, E. (2002). Wireless sensor networks: a survey. Computer networks, 38(4), 393-422.
5. www.raspberrypi.org, 10-02-2017
6. https://www.sparkfun.com/products/13678, 10-02-2017