Design and Implementation of Wireless Nurse Calling System Using Arduino

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***Abstract* - In this paper, a new design of wireless nurse calling system is discussed which is based on plug and play concept. The system is developed by using low-cost components and open source material, Arduino and nRF24L01 RF Module as a hardware while Processing language is used to design the user interface program. The wireless network is implemented via low power nRF24L01 RF Module to guarantee the security between the slave and master nodes. The graphical user interface is easy to use and uncomplicated; it simulates the hospital rooms and bathrooms.**

***Index Terms*— Arduino, nRF24l01 RF Module, Processing Language.**

I. INTRODUCTION

In the third world countries, Libya as an example, normal buildings transform into asylums and hospitals is common; these buildings are usually designed for general purposes and not as hospitals, where they lacked the infrastructure should be considered when designing health facilities, such as electrical wiring, water pipes, and gas pipes. To install some systems often is needed extensions of electrical wires through walls and floors, and this may add high costs or impair or change the design of the building. Perhaps, replacing the wiring system by wireless system is the best solution for this problem. In additional, the world is moving trend to use wireless communication, and to use Nano-scale devices [1].

Wireless Sensor Networks (WSNs) today become the most popular and common in the real world [2]. WSN is a network made up of a set of sensors (nodes) deployed in the geographic area, to collect data from the environment, and to send the collected data to the main station, Typically through the wireless channels [3]. Sensors may be used in fire monitoring in forests [4], or to measure the temperature [5], or even water monitoring or any type of sensors [6]. "Fig. 1" shows a typical Wireless Sensors Network (WSN).

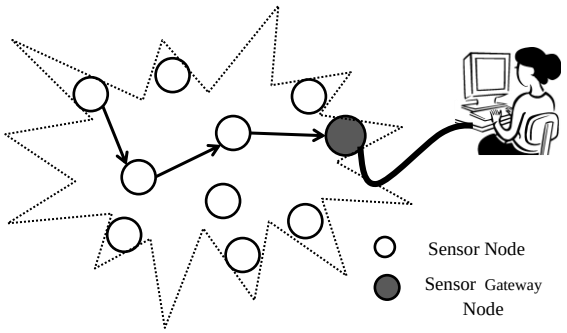

Figure 1. A typical WSN.

The proposed system is based on the nurse calling system design; the system relies on the use of wireless communication between parts of the system rather than the wired system. As a result, the cost of the system is reduced and complexities of wires are canceled as well as the aesthetic view. The rest of this paper is organized as follows. Section II explains the proposed system architecture. The system design is illustrated in section III. Section IV shows the system hardware design. The system software design is explained in section V. Finally, the conclusions of this paper are in the last section.

II. PROPOSED SYSTEM ARCHITECTURE

The proposed system architecture is shown in "Fig. 2". The figure explains the main idea of the system where nursing staff can reply to the patient by knowing his room and his bed number via an easy graphical computer interface. The proposed system uses simple (WSN) and can be expanded. In this project do not use the sensors to monitor the environment or temperature measurement or other functions that can be used for it, just its use a signal coming from the push button. The architecture of the system is based on wireless communication and (plug and play), this allows to expand the network by adding rooms or beds. The new bed is given an address and this address is added to Processing program to access the wireless network.

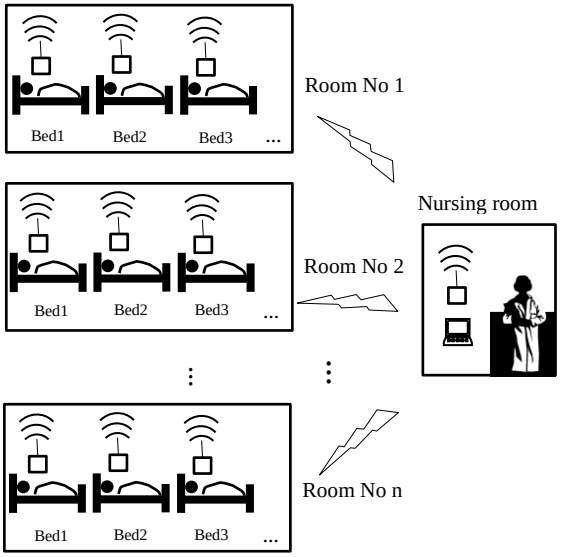

Figure 2. Proposed system architecture.

III. SYSTEM DESIGN

The system simply consists of two main parts as in "Fig. 3", the master and slave parts. The master part is located in the main nursing room, and the slave part is near the patient's bed (each bed has its own device). The master part consists of: the microcontroller (Arduino UNO) connected to the wireless module, two LEDS (green & red) and push button and a computer device. The slave part consists of: the microcontroller (Arduino NANO) connected to the wireless module, two LEDS (green & red) and push button, as shown in "Fig. 3".

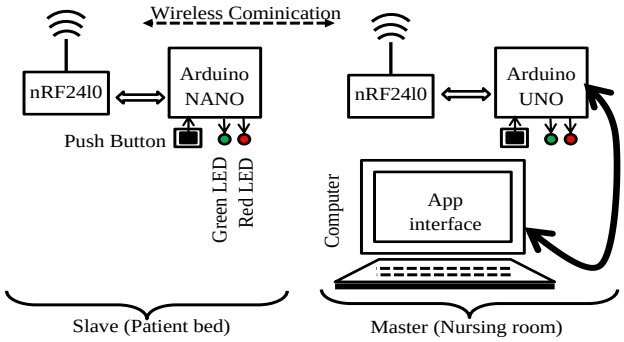

Figure 3. System design idea.

In the normal case, the green LEDs at patient and nursing room is on, but when patient pressed the push button, the red LED is on and green LED is off. Then the controller that is located at the patient's bed communicates wirelessly to the master part that is located in the nursing room using the wireless module. The master recognizes special addresses of slaves, and open a channel of communication between them. According to a unique code that the slave part has sent, the computer device with the interface shows the room and bed of the patient. The application is installed in the computer of nursing room identifies the address and the code of the patient. The program interface can show the room number and a bed in which to a help is needed. When the mouse clicks on the image of bed in the program interface, the system is informed that the request of calling is responding and the system returns to the normal case. In additional, the master part can communicate with more than one patient at the same time.

IV. SYSTEM HARDWARE DESIGN

The hardware design of the system contains several main parts: a computer, microcontroller Arduino UNO board, Arduino NANO boards and nRF24l01 wireless modules. Arduino boards and nRF24l01 wireless modules are described as:

A. Arduino UNO (used in Nursing Room)

Arduino UNO is a microcontroller board, it is a board based on ATmega328P. Arduino UNO has 14 digital pins that use as input or output pins some of them have other functions like PWM, external interrupts and serial communications protocol as UART, I2C, and SPI. Also, it has 6 analog pins, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header [7]. The board has several different types of memories as 32KB flash ROM, 2 KB SRAM and 1KB of EEPROM. The Arduino UNO board supports to add different shields that help to control other hardware, for example, a motor and GSM shields. The board can be powered directly from the computer through USB or using external DC power in the range 9 V to 12 V, the selection of the source power has occurred automatically. "Fig. 4" shows Arduino UNO board. Arduino board also comes with its programming environment, which is used to control this board by using programming language based on C, C++, and Java programming language [2] (Processing language in this paper).

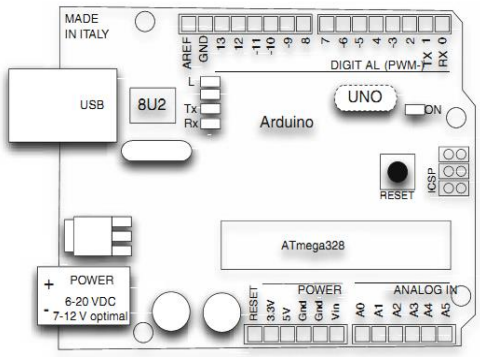

Figure 4. Arduino UNO board.

B. Arduino NANO (used in Patient Bed)

The Arduino Nano board is similar to Arduino UNO board except its size (18*45mm), so it occupies a small space and it does not support adding shields. The board

can be used in applications with a small size. The board can be powered via mini USB or external DC power supply. "Fig. 5" illustrates the Arduino Nano board.

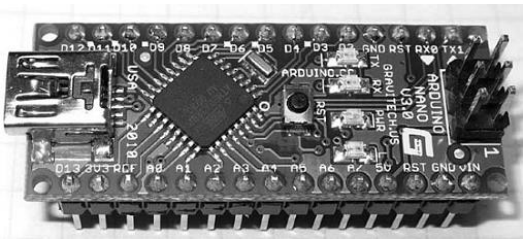

Figure 5. Arduino NANO board.

C. The nRF24l01 RF Module

The nRF24l01 is Wireless/Radio Transceiver module that can communicate with one or more microcontrollers. The nRF24l01 chip is predicted by NORDIC Semiconductor Company [5]. It uses an embedded baseband protocol engine (Enhanced ShockBurst) [8]. It is able to communicate for distance nearly 15 to 610 meters; this distance may be changed according to the places and environment. Some obstacles may affect the extent to which the transmitter and receiver, walls as an example [9]. The nRF24L01 supports (SPI) Serial Peripheral Interface it operates at 250KHz, 1Mhz, and 2Mhz where 2Mbps is maximum bit rate, 1mW transmit power and operates in the 2.4 GHz unlicensed band using GFSK modulation [9]. "Fig. 6" shows nRF24L01 RF Module and pins description.

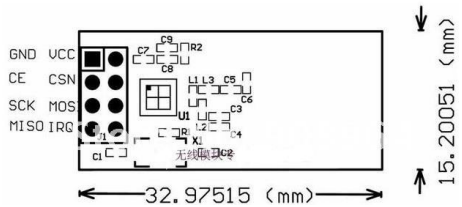

Figure 6. The nRF24L01 RF Module

The nRF24L01 has six pipes to reading, so defining each one is important. Multicevier is advantage used with RX mode. In this mode must set six parallel data pipes with a unique address. A data pipe is a logical channel in the physical RF channel. Each data pipe has its specific physical address decoding in the NRF24L01+ [9]. When using more than four transmitters together.

TABLE 1. Connection Pins (Arduino & nRF24l01).

Signal	RF Module	Arduino Pin
GND	1	GND
VCC	2	3.3V
CE	3	9
CSN	4	10
SCK	5	13
MOSI	6	11
MISO	7	12
IRQ	8	2*

All addresses should be different, and TX mode is sending data and RX made receives the same data. Table (1) explains how to connect the nRF24L01 Module with Arduino board physically.

D. The Hardware chart

"Fig. 7" describes the physical components and some of the procedures that take place between them, from Arduino at the patient's bed, through the Arduino controller to the computer in the nursing room.

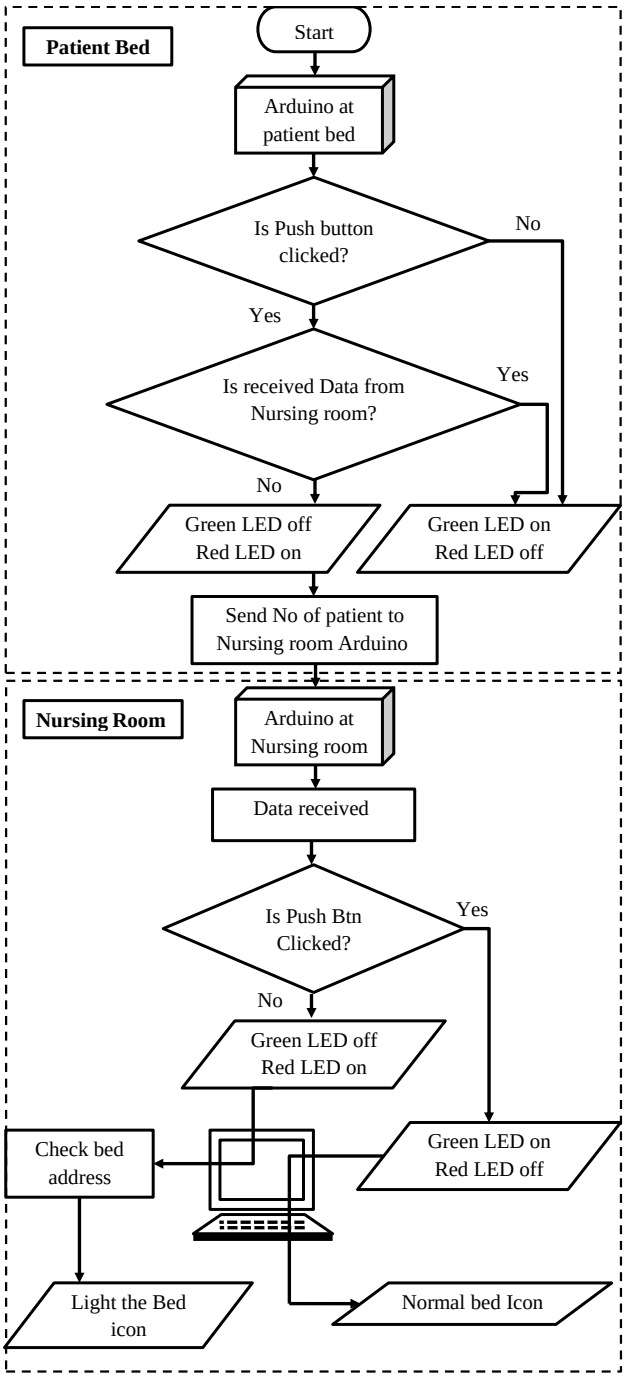

Figure 7. The hardware flow chart

V. SYSTEM SOFTWARE DESIGN

To complete the implementation of the system, some of the software tools are required to design the user interface and the other is used to program the hardware. These software tools are explained as follows:

A. Processing Language

Many different design languages can be used to implement the user interface, but Processing language is proposed. Because Processing language is a visual, open source, and OOP language, easy to communicate with the Arduino. It is established by Casey Reas and Ben Fry [10], processing is IDE oriented for designers and artists to build electronic art, also it is based on the Java programming language. It has the ability to produce the visualization things, such as shapes, maps, or graphical representation [5]. The benefit of visualization elements is it explain a big amount of data by using one graphical, also presents a simple and clear interface for users [11]. The suggested interface is designed by Processing is shown in "Fig. 8" where the logo of the hospital and the department name can be changed according to the hospital.

B. Arduino Language

Arduino language is necessary to program the Arduino boards, slaves, and master. Arduino IDE is free, open source and easy to use [7] [8]. Also, it supports free libraries that facilitate to deal with many of different hardware components such as nRF24L01 Module. To use Arduino with nRF24L01 Module RF24 Library is suggested because it is easy to use. Every bed in the room or bathroom is given a unique address to the distinction between them.

The complete proposed system is the combination of the hardware and software work together. The Arduino UNO is powered via USB because it is connected to the PC for communication, but the Arduino NANO can be powered by using wall AC – DC 9V converted or using a 9V battery. Using 9V battery can give the patient more convenient and fewer wires, but it needs to change from one period to another to ensure work efficiency.

C. Algorithm and Flowchart of program

The application or program is designed based on integration between the Arduino programming language and Processing language. The application responds by receiving data (alarm) by pressing on one of the buttons of the patient's bed. Therefore the program will respond to the request, which will begin a beep sound to alert the nurses, then will appear on the program's interface image and the bed's number and the room. The user interface and the processes of the service are shown in “Fig. 8". The nurse then clicks on the image of the bed on the screen of the computer to return the program to the normal state.

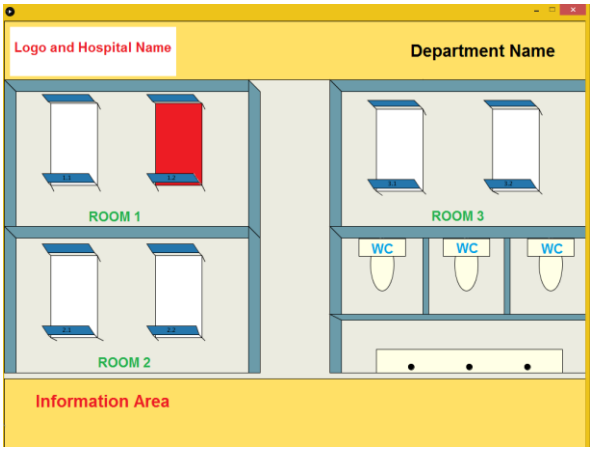

Figure 8. The user interface.

"Fig. 9" describes how the program works through the user interface program flowchart. The following algorithm describes how the program works in simple steps:

ALGORTHIM:

STEP 1: Start.

STEP 2: Wait for the alert.

STEP 3: If an alert occurs, go to the next step, otherwise go to step 2.

STEP 4: Let the beep sound running, and display the location of the bed and the room.

STEP 5: If the alarmed bed image is clicked, go to step 2, otherwise go to step 3.

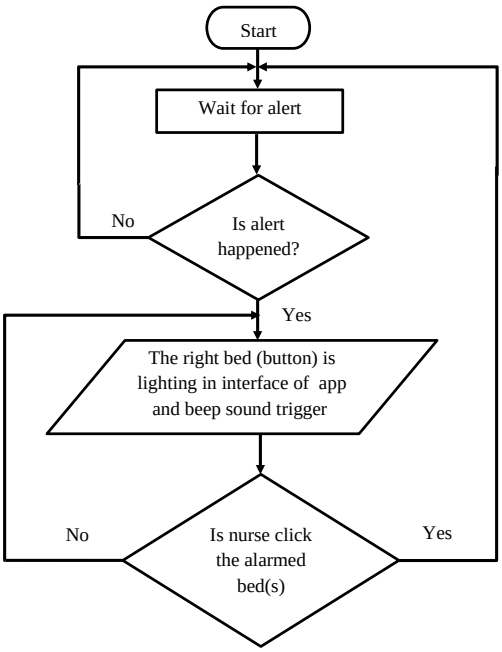

Figure. 9. User interface program flowchart.

VI. CONCLUSION

This paper has demonstrated a new idea of design and practical implementation of wireless nurse calling system (plug and play). The system was implemented using open sources software tools Arduino and Processing language, also Arduino development boards, nRF24L01 low-power RF modules. During the practical experiences of implantation the system, some problems are observed which are summarized with solutions in the following:

- The library that used RF24 Library has a problem represented by the delays in some functions after several tests. The devices are working well separately; those delays may be cause for sending and receiving data. One of the solutions was lessening the no crucial delays.
- The nRF24L01 Module has only six channels to communicate with other nRF24L01 Module, to overcome this problem, tree network is used where every six slaves communicate with one node this node can communicate directly with the master node.
- The problem of communication range varying can be solved by replacing the nRF24L01 Module with the high power transmitting nRF24L01 Module built-in external Antenna.

In the future study, the proposed system can be extended with an extra number of nodes. Furthermore, for extending the system internet shield can be used with the master node to send the data to a specific website.

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