A Novel Software Layer to Program Arduino over the Air using Bluetooth

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***ABSTRACT**--Programming over the air (POTA) is commonly used to update the firmware and configuration of a wireless sensor node without any physical contact with the node. Here we designed a four-wheel student development kit for the remote-controlled car via Bluetooth HC-05 module that was programmed using over the air (OTA). Bluetooth HC-05 module only supports universal asynchronous receive transmits (UART) traffic to communicate with connected slave devices. To implement POTA for robotic cars an additional software layer was written for the HC-05 module and this software layer makes HC-05 able to program Arduino pro mini over serial communication. The written software transfers data over the Bluetooth link to the slave hardware to program Arduino pro mini. This work can be utilized in the swarm of robotics network in which firmware consistently need to update to adapt the surrounding. It can also be utilized in the localization of robots in the indoor environment and similarly can be utilized for student training. Here we designed a four-wheel student development kit for the remote-controlled car via Bluetooth HC-05 module that was programmed using over the air (OTA).*

Keywords: Programming over the air, Arduino, Microcontroller

I. INTRODUCTION

Programming over the air (POTA) refers to a method of delivering new software to fix bugs and make crucial software improvements over the air (OTA) without having any physical access to the system. Maintenance and extensibility are the two important steps that require regular software updates, these updates can easily be provided by using OTA. The concept of wireless programming commonly known as POTA has been used in the past years for the reprogramming of mobile devices, but with the emergence of the new concepts of the machine to machine (M2M), internet of things (IoT), wireless sensor network (WSN), software-defined sensor networks (SDSN) and OTA is taken more significantly [1-5]. As it is often necessary in the case of wireless sensor networks to reprogram the nodes and usually the nodes are operating in an isolated environment, so in such cases, the concept of POTA has a great significance. The significant advantage of POTA is listed below.

1. In critical applications such as electrical metering where downtime is very important, OTA allows us to recover the issues quickly.
2. Enables us to remotely upgrade a system, without having any physical access to the system.
3. Overall its time saving, as in the training phase we often want to reprogram the node.
4. Initially and originally it is used to update firmware for mobile handsets.
5. Update new program in few seconds, due to high uploading speeds.

Due to the advantages offered by the POTA, it has a wide area of applications. POTA was initially developed to allow device manufacturers and network operators to deliver updated firmware for mobile handsets, the growing new concepts of M2M, IOT [6], WSN, use the POTA technology in the same way and it reduces half of their complexity. POTA is a fundamental requirement and servicing technique in the emerging field of wireless sensor networks where both maintenance and management are challenging tasks.POTA is also utilized for one or more mobile devices which are reprogrammed over the air using dedicated control channels. In [7] the authors proposed a method to reprogram a mobile device using a broadcast control channel. The mobile device is configured to accept or reject currently approved channels. In [8,13] author uses POTA to program and update a dual-satellite emergency locator beacon. In [9,11,12] media access control (MAC) address was associated with the device using the MAC address server. While in the production line the device connects to a wireless network, MAC server when detects this connection it determines the available MAC addresses and communicates the MAC address to the device over the wireless network. This address acts as a source address that the device will utilize in the future for further communication sessions. In WSN performing OTAP requires many challenges like flexibility, reliability, and security. This is because when these network nodes are deployed in

remote areas they might be reprogrammed to update their firmware. But the environment can make it impossible to reprogram those nodes. So only possibility to reprogram those nodes is to use POTA, but using POTA rises a challenge of security. In [10] authors proposed a cybersecurity protocol to help WSN with proper communication and authentication. So by investigating these design challenges up to the present and keeping in mind the advantages of POTA in sensor networks we implement it in the field of robotics and wireless sensor networks, as in the case of robotics it is often necessary for a beginner to reprogram it as many times while not achieving the desired results. As it is not agreeable to take back the robot from the arena for just the purpose of reprogramming. Similarly, in the case of WSN, a node is usually fixed in a particular location to sense its surroundings and sending back the data to the server-side. To make the sensor node adaptable to surroundings, the firmware needs to be updated so to get good results from the sensor node in robotics it is usually required to reprogram it several times to achieve desired results. So the concept of POTA fits properly in our situations and reduces the overall efforts so we use it.

II. PROPOSED SYSTEM

Figure 1 shows the hardware module that was programmed using POTA. As shown in figure 1 the proposed system consist of mainly two parts, one is Arduino pro mini and a pair of HC-05 Bluetooth modules. The other components on the boards are the voltage regulator and ultrasonic sensor used for additional functionalities.

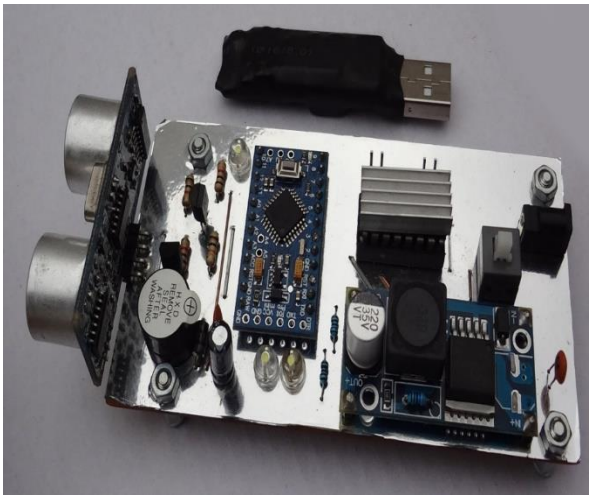

Fig. 1. Hardware module for robotic car

The connection between Arduino pro mini and Bluetooth module HC-05 is shown in figure 2 below. To program serially we had to push that reset button before sending configuration setting over bluetooth channel.

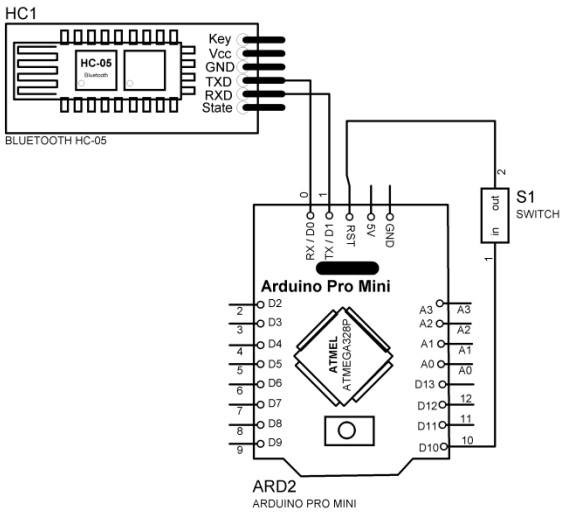

Fig. 2. HC-05 connection with Arduino pro mini

On the other end the second pair of HC-05 is connected to computer. These devices are paired using standard bluetooth communication and after successful communication same bluetooth which is connected to Arduino pro mini is utilized to program controller unit.

III. RESULTS AND DISCUSSIONS:

This section consists of three parts

1. Hardware
2. Software
3. Experiments

A. Hardware.

As we know a special programmer is required to program a microcontroller, but after the development of the Arduino board, it was made possible to program a controller using standard universal asynchronous receive transmit (UART). To program a microcontroller via UART we require a bootloader and bootloader is a piece of code that was used to program flash memory of the microcontroller via serial or USB instead of utilizing a special programmer device. Therefore if a bootloader is burned on the chip there is no need for the external programmer, the same idea is implemented for Arduino pro mini as no onboard programmer is available for this kit. To use Arduino pro mini to design a student development kit for a remote-controlled car we first design POTA hardware.

To explain how the boot loader works we draw figure 3. As in figure 3, an external converter is used FDTI232. Now to program the microcontroller via

FDTI232 we just have to connect it with the computer universal bus. Briefly, a bootloader makes us enable to program Arduinopro mini simply through UART pins and a third pin to reset the microcontroller, this is shown in figure 3. When the bootloader starts it looks for valid traffic on the UART, if there is something valid on UART it will receive it and store it into the EEPROM, this is how the Arduino is programmed over UART.

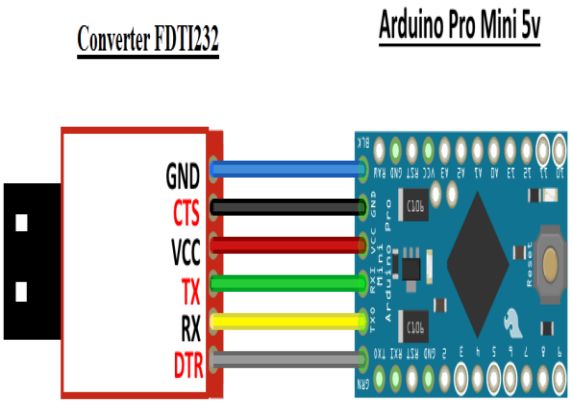

Fig. 3. Arduino pro mini UART programmer

The programming Arduino mini shown in figure 3 is a wired communication process. Now by programming, the Arduino wirelessly is a great deal to achieve for a programmer. To program Arduino we have to physically plug out the controller from the circuitry or we have to physically connect the controller with the programmer or computer. Now, this is quite a problem where complex circuitry is utilized. And the best way to avoid this is to use POTA.

As it is very useful where we have no physical access to the Arduino deployed hardware and we want to reprogram it. So to program the Arduino pro mini over POTA, on the computer side a USB dongle is designed which makes us able to communicate with the Arduino pro mini using a Bluetooth communication link. Now to program it wirelessly we must provide Arduino pro mini with a UART interface this is shown in figure 3. Therefore the Arduino side Bluetooth HC-05 solves this issue by providing us the UART pins this is shown in figure 2 where the Bluetooth module provides a UART interface. The complete hardware interface for POTA programming is shown in figure 4.

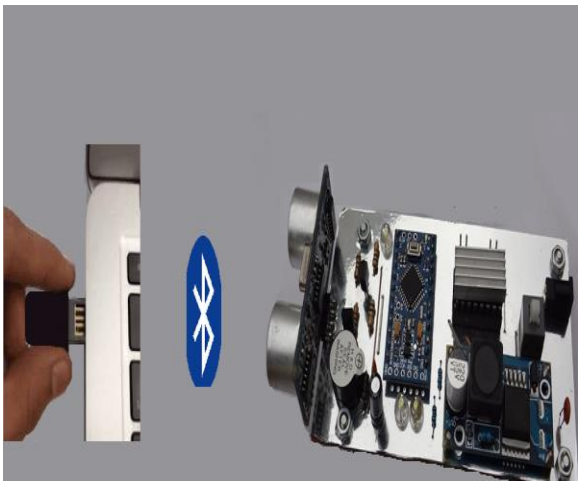

Fig. 4. POTA Hardware Interface

B. Software.

The software was written in C#, the main purpose of writing this software is to reduce the overall complexity, as we open the software and click the upload button it automatically send the reset command to the Arduino and immediately after trigger the Arduino IDE to upload the code. Figure 5 shows the developed software interface

Here the software is programmed and designed in such a way that if specific characters are sent to the Arduino pro it reset itself as it reset itself we immediately upload the code. The software can only be used when the Bluetooth dongle is attached to the computer, otherwise, you are unable to use it, when the software is initiated firstly it checks for the Bluetooth dongle if it is attached then it opens up, otherwise, it quits itself. The uploading speed that is predefined in the bootloader is 57600 bit/sec, it is reasonable enough to upload the code just in few seconds, there was an LED attached with the UART communication pins that blink and provide us the status of the uploading process. The whole working flow is as follow,

1. Connect the Bluetooth to the computer, open the Arduino IDE and write your code and finally verify it,
2. After verifying the code open the POTA software, and make sure the Arduino kit is powered on, and also that the Bluetooth is paired.
3. Now click the upload button of the software, and wait for a few seconds and you will see the uploading done message on the status bar of Arduino IDE.

For security enhancement, the master Bluetooth module only pairs with that specific slave, so that a non-authorized person may not be able to hijack the

whole system, as well as on the other side the specific reset command is hidden inside the code of the software so no one can harm the system in anyways.

C. Experiment.

The proposed system has the ability to wirelessly program the Arduino over the Bluetooth. To test this feature a robot kit is designed as shown in the figure 5.

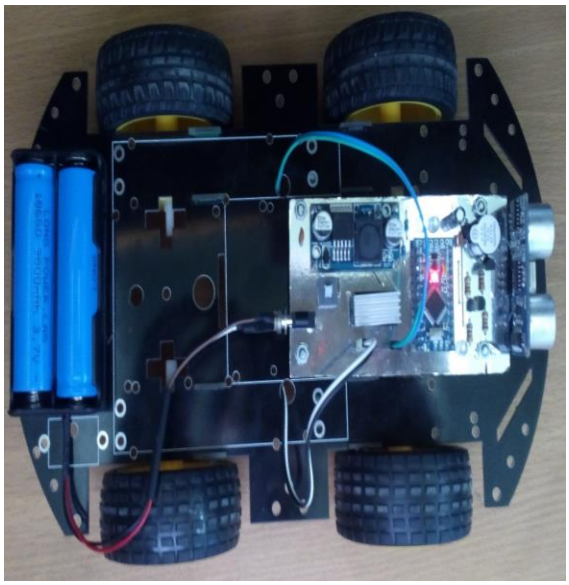

Fig. 5. Four wheel drive Robot kit

The four wheel drive robot kit as shown includes Arduino pro mini, an ultrasonic sensor, H-Bridge, Bluetooth module, and LEDs as status indicators, the Bluetooth chip is mounted on the back side of the PCB, and this is shown in figure 6.

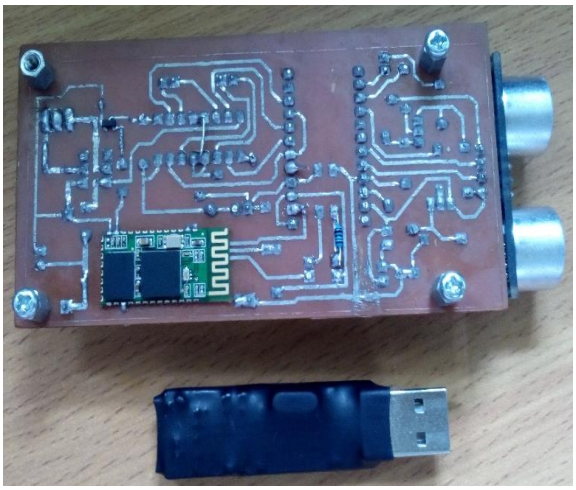

Fig. 6. Back side of four wheel drive PCB with USB dongle

Finally, we power it and connect the Bluetooth dongle to the computer to link them. As the LED turns on giving us the status that the connection is established, so it is ready to be programmed. After that, we opened the Arduino IDE and write a basic starter code for a kit, and after verifying the code is uploaded using POTA software. We just click the upload button and after few seconds the code is successfully uploaded to the Arduino. After successfully uploading the code we click on arrow keys to move the robot.

IV. CONCLUSIONS

This paper presents a method to program Arduino pro mini over the air without any physical interface with the system. This work can be utilized in the swarm of robotics network in which firmware consistently need to update to adapt the surrounding. It can also be utilized in the localization of robots in the indoor environment and similarly can be utilized for student training. Here we designed a four-wheel student development kit for the remote-controlled car via Bluetooth HC-05 module that was programmed using over the air (OTA). Bluetooth HC-05 module only supports universal asynchronous receive transmits (UART) traffic to communicate with connected slave devices. To implement POTA for robotic cars an additional software layer was written for the HC-05 module and this software layer makes HC-05 able to program Arduino pro mini over serial communication. The written software transfers data over the Bluetooth link to the slave hardware to program Arduino pro mini. This kit is optimized in design and can be utilized to teach students about remote control cars.

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