Design & Development of Daughter Board for Raspberry Pi to support Bluetooth Communication using UART

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***Abstract*—Reliable and secured communication between two or more devices require wired connection. A wireless communication such as – Bluetooth, WI-Fi, ZigBee etc. provides flexible and inexpensive solution for remote applications. A large number of low cost hardware platforms such as Raspberry Pi, Arduino, mbed boards etc. are available that do not provide any inbuilt wireless module but are equipped with UART, I2C ports for design and development of Internet of Things (IoT) and embedded applications. Designers face the difficulty to use such a low cost hardware for wireless communication in order to implement these applications. In this paper, Design & Development of Daughter Board for Raspberry Pi to support Bluetooth Communication using UART is proposed as an integrated solution. Results of various QoS parameters such as transmission rate, file format(text, pdf, image & audio), baud ratesand range for Bluetooth communication between two devices are presented. The result shows that Bluetooth module is capable of transmitting files of same size in different format approximately in same time. Proposed solution can further be extended to different protocols such as Wi-Fi and ZigBee etc.**

Keywords- Bluetooth, Raspberry Pi, UART, SoC

I. INTRODUCTION

Communication is a process of transmitting and receiving files to and from a system which consists of transmitter, receiver and a channel. A transmitter serves the purpose of sending files, Receiver receives files and channel (wired or wireless) is the middleware through which communication takes place. Wired communication making use of wires provides high speed of transmission, great reliability and security while transmission. Wired communication between remote devices becomes difficult, complex and costly due to cabling, socket fittings and requires high maintenance cost. These problems were overcome by the concept of wireless media.

Wireless communication offers wireless channel via. Bluetooth, ZigBee, WI-Fi, Infrared waves etc. for data transmission where data security, reliability is compromised to a certain level. Widely available and acceptable wireless communication protocols such as:

Bluetooth based upon IEEE 802.11.1a standard provides personal area network and utilizes unlicensed ISM band of 2.4 GHz providing transmission range up to 10-100meters[1]. **ZigBee**based up on IEEE 802.11.14 standard operates on 2.4 GHz ISM band utilizesdirect sequence spread spectrum technique (DSSS). It works on principal of LOSwhich is capable of providing transmission range up to 70 meters with a benefit of low power.**Infrared** provides line of sight communication for short range between transmitter and receiver.**Wi-Fi** wireless fidelity, based upon IEEE 802.11a/b/g standard is capable of providing data rates up to 54 mbps [3].

In this paper, Bluetooth serial communication is implemented via. Serial communication using Raspberry Pi's UART. In the rest of paper section II explains system architecture, section III implements the proposed architecture, section IV brings out the analysis of result and section V comprises of conclusion and future work.

II. RELATED WORK

As mentioned above, wireless communication between two devices can be achieved via Bluetooth, WI-Fi, Zigbee and Infrared modules. In[16], Infrared communication has been performed between two computers using PIC microcontroller. In [17], the communication between LED-to-LED networks of toys with smart phone has been achieved by visible light communication. In [18], home automation system has been described which performs GSM communication between an android mobile device and central FPGA microcontroller. In[24], all existing wireless communication technologies such as Bluetooth, WI-Max, WI-Fi, GSM, GPRS etc. which are used to connect two devices are discussed.

Since, large wireless data transfer needed to be cost effective according to required application as mentioned(mainly for file transfer) the comparison between contemporary wireless modules is presented in the Table 1 [25][26][27][28] below:

Table 1:Comparison between contemporary wireless communication modules

S. No	Features	Wi-Fi (ESP8266)	Zigbee (XB24-AWI-001)	Serial Bluetooth Module
1.	Standard	IEEE	IEEE 802.14	IEEE

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		802.11/b/g/n		802.11.a
2.	Interface Type	UART, SPI	UART	UART
3.	Range	400 meters	90 meters	10 meters
4.	Point to point link	Yes (No line of sight)	Yes (Line of Sight)	Yes(No line of sight)
5	Data Rate	150mbps	250 kbps	2.1 mbps
6.	Security	Password protected	Password protected	Password protected
7.	Cost	550 INR	1600 INR	950 INR

In this paper, Raspberry Pi is a new hardware platform providing all the functionalities similar to personal computer or laptops but is not equipped with any inbuilt wireless facility for providing wireless data transfer.Since the application requirement is to achieve data transfer within the range of 10 meters with no line of sight. Bluetooth is chosen as WI-Fi requires internet connection all the time that leads to extra dependability. For chosen functionalities Bluetooth is found more cost efficient for overall operation. Bluetooth functionality can be achieved by using Bluetooth dongle but it requires an extra USB port. Since, Raspberry Pi model B has limited number of ports which hampers the addition of another USB devices such as keyboard, mouse etc. This provided the motivation behind addition of Bluetooth module with Raspberry Pi via UART. Hence, Table 2[19][20][21][22][13] and Table 3[23] shows extensive survey on the easily available Bluetooth module to carry out ordinary wireless data transmission and HC05 has been chosen due to its low cost and easy availability in nearby market.

Table 2: Comparison between different-available Bluetooth Modules

S. No.	Features	Ver.	Class	Data Rate	Interface Type
1.	BISMS02BI	V2.0	Class 1	300kbps	UART
2.	Bluecore-2	V1.1, V1.2	Class 2	723.2 kbps	UART
3.	HC05	V2.0+EDR	Class 2	1 mbps	UART
4.	Eb 506	V1.2	Class 2	721 kbps	UART
5.	RN42	V2.0	Class2	921 kbps	UART, USB

Table 3: Bluetooth Class Categorization

Class	**Operating Range**	**Maximum Power**
Class 1	100 meters/300 feet	100 mw (20dbm)
Class 2	10 meters/33 feet	2.5 mw (4dbm)
Class 3	1 meter/3 feet	1 mw (0dbm)

III. SYSTEM ARCHITECTURE

The proposed system architecture consists of two Raspberry Pi and two Bluetooth modules which are connected through UART.

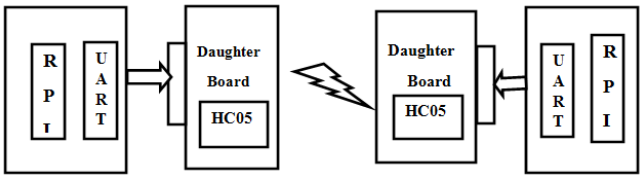

Fig.1: System Block Diagram

A. Bluetooth

Bluetooth is a technology that operates in master-slave mode, where master and slave together forms a Pico-net. It provides two modes of communication i.e., point-to-point (pairing is required) and broadcast. Bluetooth protocol stack based upon IEEE 802.11.1a standard comprise of Bluetooth core protocols (Baseband, LMP, L2CAP, SDP), cable replacement protocol (RFCOMM), Telephony Control protocol (TCS BIN, AT Commands) and adopted protocols (PPP, TCP/IP/ OBEX) [2].

There are wide range of various available Bluetooth modules such as RN41, HC05, RN42 and Blue Link Gold Class-1 etc. HC-05 has been selected for implementing and testing with desired platform i.e., Raspberry Pi due to its easy availability and cost effectiveness [13] [14].

HC05 is a V2.0 Bluetooth module utilizing UART profile operating at +3.3v DC/50 mA. It is capable of transmitting at 9600-115200 bps data rate and providing speeds up to 2.1 Mbps (max) in asynchronous mode and 1.0 Mbps in synchronous mode [11][12].

B. Raspberry Pi

Raspberry Pi is a small sized computer board consists of RISC architecture based processor ARM 11, 700 MHz processor. It is equipped with SoC “BCM 2835” providing on board 512 MB of SDRAM, an interface for output unit such as VGA Monitor, touch screen and input unit such as keyboard, keypad, and mouse.

B.1Serial Communication

Serial Communication is a form of communication providing bits of bytes being transferred being serially [6].Serial Communication includes I2C, SPI, UART, USB etc. Raspberry pi is equipped with 2 SPI, 1 UART and 1 I2C [10].

Proposed work has been implemented and tested by interfacing Bluetooth module to Raspberry Pi UART at two systems. UART is Universal Asynchronous Receiver

Transmitter which transmits data serially by placing data between start bit and stop bit [6].

IV. IMPLEMENTATION

Raspberry Pi supports image of DebianLinuxOS as its operating system which is a open source. Debian image has been ported to SD card using window base disk image writer [7].

A. Configuration & set up for Raspberry Pi (RPi)

Debian Linux OS is well equipped with 37,000 packages that needs to be installed and imported during configuration [7]. Prior to implementation, Serial port of RPi needs to be configured by installing necessary and required packages as described below [8] [9]:

1. Install python: To install the latest version of python sudo apt-get install python.**Command: sudo apt-get install python**
2. Install Python-dev: to set up the python development environment i.e., to install and compile the packages for latest version of python .**Command: sudo apt-get install python-dev**
3. Install libjpeg-dev: To get the support for jpeg image functionality.**Command: sudo apt-get install libjpeg-dev**
4. Installing libfreetype6-dev: It provides type related services. **Command: sudo apt-get install libfreetype6-dev**
5. Installing python-setuptools: It consists of enhancementsof the python distutils to allow developers to more easily build and distribute Python packages that have dependencies on other packages.**Command: sudo apt-get install python-setuptools**
6. Install python-pip: It is used to download and install packagesdirectly from PyPI i.e., Python Package Index.**Command: sudo apt-get install python-pip**
7. Install RPi.GPIO: It offers easy access to general purpose IO pins on the Raspberry Pi.**Command: sudo pip install RPi.GPIO**
8. Install pySerial: To access the serial Port.**Command: sudo pip install pySerial**
9. Install nose: It extends the unit test to make testing easier.**Command: sudo pip install nose**
10. Install cmd2: A python package for building powerful command-line interpreter(CLI) programs. Extend the python Standard Library's cmd Package. The basic use of cmd2 is identical to that of cmd.**Command: sudo pip install cmd**

By default, the serial port of RPi act as a console. The following precedence is used to free the serial port for use:

1. Commenting out a line in /etc/inittab:
To:23:respawn:/sbin/getty –L ttyAMA0 115200 vt100

2. When the Pi is booting,all the debug messages are sent to the serial port. These messages need to be stopped. This is done by editing the cmdline.txt file.

sudonano /boot/cmdline.txt and finding the line to
"dwc_otg.lpm_enable=0console=tty1 root=/dev/mmcblk0p2 rootfstype=ext4 elevator=deadline rootwait".

B. System Work flow

The proposed implementation is depicted step by step through the flow chart described in figure2:

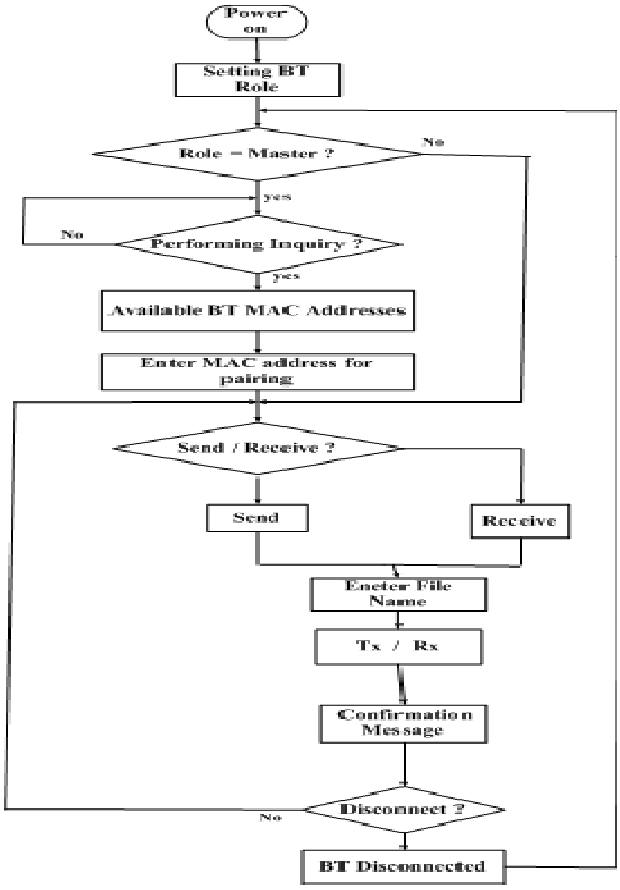

Fig.2: System flow chart

Bluetooth module operates in data mode and command mode. The system starts by entering into command mode where Bluetooth role is configured to master which further performs enquiry. Pairing is done with desired Bluetooth

device and Bluetooth enters into data mode from where bidirectional communication occurs.

V. PERFORMANCEANALYSIS

Performance of proposed system has been analyzed on the basis of QoS parameters such as transmission rate, file format (text, pdf, image & audio), baud rates and range. All experiments are carried out in same operating environment created in the lab.

Class 2 Bluetooth module HC05 supports transmission range up to 10 meters and baud rates ranging from 9600 to 115200. However,experiments are performed for 0.30m, 8m & 10 m at 9600, 19200 & 38400 for pdf, txt, wav and jpg formats these file formats.These formats arecommonly used in wireless sensor network for data transmission and IoT applications.

A. Different file sizes in different formats at 9600 Baud rate

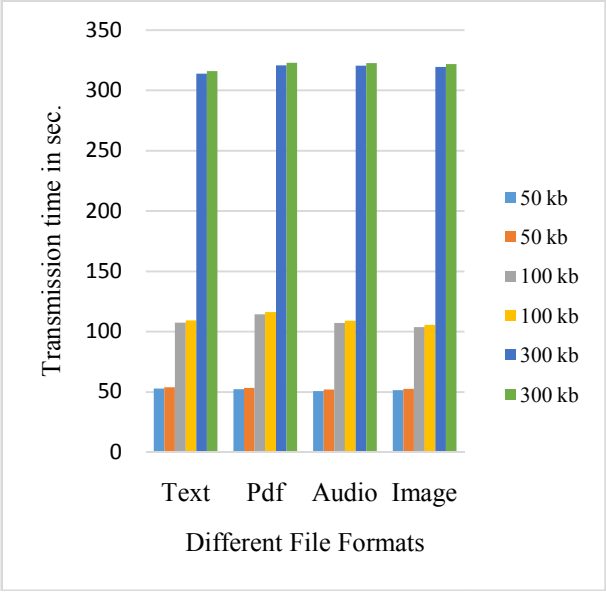

Fig.3: Tx vs Rx for different file sizes at 9600 baud rate

The graph shown in fig.3depicts that for 9600 baud rate, the time taken for reception and transmission of files of same size i.e., 50 kb, 100 kb & 300 kb of different file format i.e., pdf, txt, wav & jpg is same. However the small variation is due to the non-availability of exact file sizes in different formats.

B. Tansmit & Receive time for different file sizes at different Baud rate

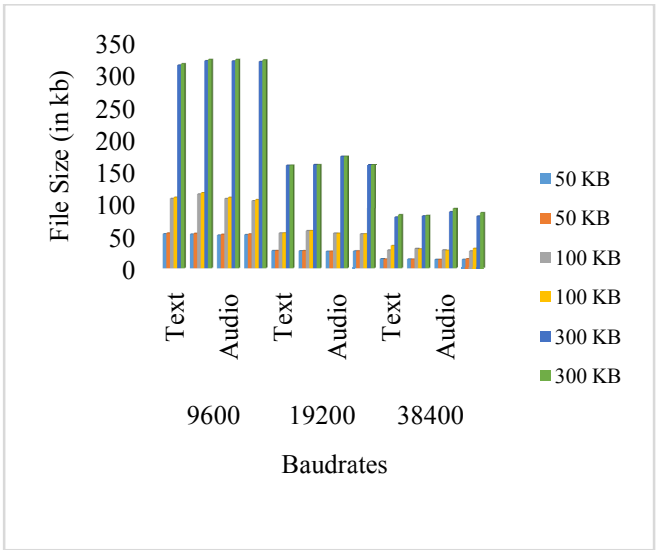

Fig.4: Rx &Tx of different file size vs Baud rate

The time taken for Transmission and reception reduces proportionally as baud rate increasesirrespective of file sizes and file formats as shown in figure 4.

C. Different file format for different range at 9600 Baud rate & 19200 Baud rate at different range

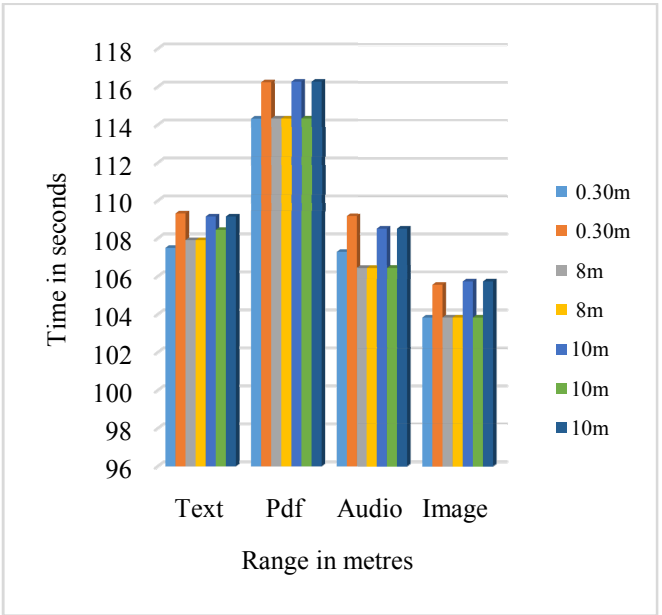

Fig.5: Tx& Rx for different file formats Vs range at 9600 Baud rate

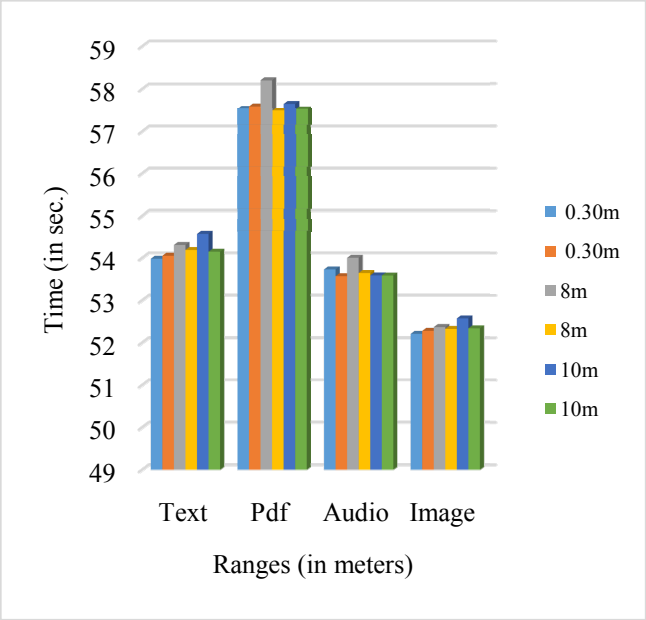

Fig6:Tx& Rx for different file formats Vs range at 9600 Baud rate

The time taken for Transmission and reception reduces proportionally as baud rate increases irrespective of range formats as shown in figure 5 & figure 6.

VI. DESIGN CHALLENGES

The results and analysis showed successful transmission between two devices but there were some challengesfaced during these analysis and are listed as under:

- Measurement of signal strength with respect to distance
- Measurement of power consumption with respect to distance.

Due to non-availability of required resources, this paper lacks above mentioned analysis.Apart from these it was noted that extra cautionis required while providing power supply and switching between Bluetooth operational modes.

VII. CONCLUSION & FUTURE WORK

Design & Development of Daughter Board for Raspberry Pi to support Bluetooth communication using UART has been tested and implemented.The experiments are carried out using Raspberry Pi operating at 700 MHz and Bluetooth module HC05in the university campus.

The experimental results show that:

- Irrespective of file formats time taken for communication remains same for same file size.
- Increase in baud rate reduces transmission & receiving time.
- Within the range (up to 10m) communication time remains same fordifferent file formats of same size.
- Increase in baud rate results in proportional decrease in time.

Based on above analysis the conclusion is drawn that HC05 Bluetooth module is suitable for design and development of daughter board that supports Bluetooth communication for Raspberry Pi.

The future work involves study and implementation of other wireless modules as mentioned Table 1 for different hardware platforms insimilar way and accommodation of those findings into respective daughter boards.

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