Design, Development and Implementation of the IR Signaling Techniques for Monitoring Ambient and Body Temperature in WBANs

ATTIYA BAQAI*, FAHIM AZIZ UMRANI**, AND BHAWANI SHANKAR CHOWDHRY***

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ABSTRACT

Healthcare systems such as hospitals, homecare, telemedicine, and physical rehabilitation are expected to be revolutionized by WBAN (Wireless Body Area Networks). This research work aims to investigate, design, optimize, and demonstrate the applications of IR (Infra-Red) communication systems in WBAN. It is aimed to establish a prototype WBAN system capable of measuring Ambient and Body Temperature using LM35 as temperature sensor and transmitting and receiving the data using optical signals. The corresponding technical challenges that have to be faced are also discussed in this paper. Investigations are carried out to efficiently design the hardware using low-cost and low power optical transceivers. The experimental results reveal the successful transmission and reception of Ambient and Body Temperatures over short ranges i.e. up to 3-4 meters. A simple IR transceiver with an LED (Light Emitting Diodes), TV remote control IC and Arduino microcontroller is designed to perform the transmission with sufficient accuracy and ease. Experiments are also performed to avoid interference from other sources like AC and TV remote control signals by implementing IR tags.

Key Words: **Free-Space Optical Communication; Wireless Body Area Networks, Infra-Red, LOS, Infra-Red Tags, Arduino.**

1. INTRODUCTION

It is expected that in future wireless communication systems connectivity will be present everywhere, integrating devices faultlessly operating in most common conditions, ranging from static and less-mobility indoor environments at one end to high-mobility cellular systems at the other end. The optical links rather than RF (Radio Frequency) are catering the need of providing short-range wireless communications in most parts. Perhaps the major share is taken by WLAN (Wireless Local Area Networks) and WBAN for practical applications of short-range communications, which covers distances from a few tens of meters down to sub-meter communications [1]. WBAN comprises of a set of mobile and compact intercommunicating sensors, which can be wearable or implanted into the human body. These sensors monitor vital body movements and parameters. Vital body conditions and movements can also be monitored continuously, such as asthma, diabetes, and heart attacks. Wireless technologies are used by these devices to communicate such as UWB (Ultra-Wide Band), Microwave, and OW (Optical Wireless) etc. [2-7].

* Assistant Professor ** Associate Professor, and *** Meritorious Professor
Institute of Information & Communication Technologies, Mehran University of Engineering & Technology, Jamshoro

Majority of WBAN systems bank on utilizing RF signaling techniques such as Bluetooth, UWB or Smart Bluetooth. Very little work is carried out on exploring OW techniques such as IR for such system, despite their obvious advantages. In this work, therefore, a WBAN prototype system is designed and implemented using IR transceivers.

The paper is organized as follows. The comparison between radio and optical signaling techniques and justification for choosing the optical signals is argued in the Section 2. In Section 3, we define system hardware for the temperature sensors in WBANs and discuss in detail the transceiver design for data acquisition, transmission and reception. We also use IR tags for patient identification and interference cancellation and present our experimental setup. Results and observations are presented in Section 4 and conclusion in Section 5.

2. COMPARISON BETWEEN RADIO AND OPTICAL SIGNALING TECHNIQUES

For many reasons, optical communication is preferred in certain cases. For example, optical communications provide high bandwidth at low cost, is immune to EMI (Electromagnetic Interference), the spectrum is freely available, and infrared components are inexpensive, small, lightweight, and consume little power [8]. Therefore, the focus of this paper is short-range optical wireless communication systems. As IR dominates optical communication systems for short-range applications, so from now on, optical communication will be used interchangeably with IR in this paper.

The bandwidth of OW channel is in the range of THz which is unregulated and having characteristics that are different from radio characteristics. Due to the fact that the optical signals have high frequency they are likely to be more directional in comparison to their counterpart RF signals. Additionally, optical signals do not penetrate solid things such walls, whereas at lower frequencies RF signals have the capability to freely propagate from or over solid subjects like walls. Dark objects absorb them, whereas light-colored objects diffusely reflect them and shiny surfaces reflect them directionally. IR transmission is capable to pass through glass, but not from opaque structures such as walls and ceilings which implies that interference avoidance can be achieved by utilizing the same optical carrier in a neighboring room [8,9].

Both RF and optical signals can rebound from several surfaces such as walls, water, mirror and buildings. The traveled distance along with recovery by the receiver by both kinds of signals relies upon the medium of signal propagation, the signal originally transmitted strength i.e. energy and the receiver's sensitivity. Normally the signals become weaker as the distance increases [10,11].

Practically the devices meeting the requirements of Short-Range IrDA (Infrared Data Association) [12], specifications for Data Physical Layer and having standard IrDA 1.0 and 1.1 the restriction on distances is 1.0 meter. At 1.0 meter distance devices offer almost free of error communication with 115.2 Kb/s data rate. For transmitting at longer distances about 30-40 ft. there are Directional transmitters (IR LEDs)

Contrary to RF systems, IR systems do not suffer from the effects of fading, because of small wavelengths of IR in comparison to the detector size. The absence of fade and the positional stability (slow moving or static objects) of the indoor environment implies that the characteristics of IR channel stay steady for significant periods of time. Even though multipath fading is diminished in infrared systems, multipath propagation does lead to dispersion, resulting inter-symbol interference in high-speed systems [9]. Utilization of the diffuse channels has the benefit of robustness to shadowing or misalignment between the transmitter and the receiver. This comparison between Radio frequency and Infrared is summarized in Table 1.

TABLE 1· COMPARISON OF RADIO FREQUENCY WITH INFRARED

Parameter	RF	Infrared
FCC/RCC Regulations	Yes	No
Security	Low	High
RF Interference	Yes	No
Cost	Variable	Potentially Low
Main Noise Source	Other User Interference	Ambient Light
Coverage	Medium	Low
Mobility	Yes	Some Configurations (Diffused)
Bandwidth Limitations	Regulatory	Photo-Detector/ Preamplifier, Diffuse Channel
Multipath Dispersion	Yes	Some Configurations
Multipath Fading	Yes	No
Path Loss	High	High

Unfortunately, WIR system has severe drawbacks. Ambient light, shot noise, path loss and dispersion associated with diffuse infrared systems multiple access interference are the major dominant impairments in WIR systems. The path loss, shot noise and dispersion motivates for the necessity of high optical transmit powers. Still, infrared transceiver's average emitted power is restricted by rules of eye safety and electricity consumed by battery-powered portable devices. Thus, it follows that the usage of a power efficient modulation scheme would be best needed, so that peak to average power level can be maximized. [10-14].

3. SYSTEM HARDWARE AND SOFTWARE

The complete project for testing the feasibility of IR communication is made by choosing the least expensive and easily available components which are described as follows:

3.1 Temperature Sensor and Data Acquisition

The sensor that was chosen for real time data acquisition is LM35 temperature sensor easily available in market of PKRs. 100/-. The temperature data was acquired from the sensor using Arduino UNO It was tested and compared first with the characteristics given in data sheet to measure room temperature and then calibrated to measure body temperature accurately [15].

After testing LM35DZ temperature sensor for ambient temperature its readings were compared with Digital Hygro thermometer to verify the results and accuracy and it was found that the results were with accuracy of 0.2^0C as shown in Fig. 1(a).

LM35DZ was tested to cover body temperature range and readings were taken at various body places to find its feasibility for measuring body temperature as well. This data was verified with the help of Citizen Digital thermometer CT561F for clinical use as shown in Fig. 1(b) and it was found that the sensor used in our system was giving acceptably accurate results with accuracy in the range of 0.4^0F. The readings and observations taken from digital thermometer are given in Table 2.

FIG. 1(a). TEMPERATURE READING VERIFICATION WITH THE HELP OF DIGITAL HYGRO THERMOMETER

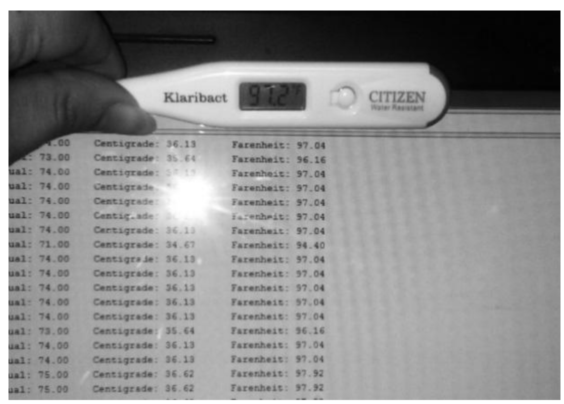


FIG. 1(b). TEMPERATURE READING VERIFICATION WITH THE HELP OF DIGITAL THERMOMETER CT561

TABLE 2.TEMPERATURE READINGS AT VARIOUS PLACES IN HUMAN BODY IN ^{0}F AT 20.1^0C ROOM TEMPERATURE

Sensor	Palm Reading	Neck Reading	Elbow Joint Reading	Ear Lobe	Temporal Reading	Armpit Reading	Mouth Reading
Digital Thermometer	94.8	97.2	94.5	95.9	96.2	97.6	97.4
LM35DZ	94.6	97.04	94.8	95.5	96.16	97.4	N/A
Error	0.2	0.16	0.3	0.4	0.04	0.2	N/A

The temperature sensors is placed on neck, temporal and auxiliary positions since at these positions the temperature readings are more accurate and reliable as can be deduced from Table 2.

3.2 Transmitter

It comprises of one, or multiple sources, also it requires optical element to shape the beam and also make it eye-safe according to requirement. The optical source is the key component of the transmitter. Two most commonly used types of optical sources are: LED and laser diodes. The near IR region (i.e. between the visible and 1400nm) has the bound for point sources which is not more than 1mW. Beyond 1400nm this limit increases by a factor of 20 or so. Because Laser diodes have higher modulation bandwidth and efficiency they are used by majority of the systems. For creating optical links the optical source of IR LED is also under consideration [14,16].

For this project IR LED of 940nm Wavelength is chosen as a transmitter, the sensed temperature is read by the microcontroller which is then transmitted through PWM pin of the arduino board. This simple transmitter only consists of a resistor, a microcontroller and an IR LED as shown in Fig. 2 [17].

3.3 IR Tags

The IR tags are inserted in the temperature readings through programming to avoid interference from multiple sources like ambient light, TV/AC or other appliances remote controls etc. Our developed format of packet is of 4 bytes (32 bits); it includes data, IDTAG and sum of the ID digits for checking errors as well double check of authentication of the person. The format is shown in Table 3.

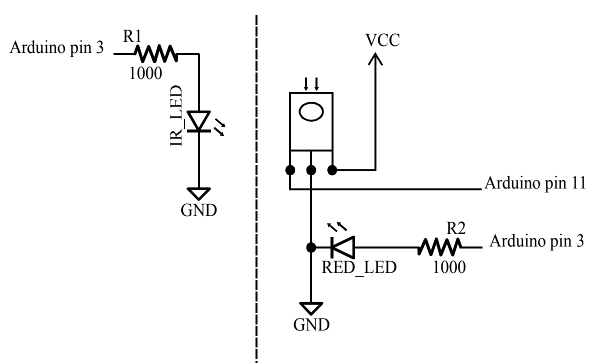


FIG. 2. CIRCUITS FOR SIMPLE IR TRANSMITTER AND RECEIVER

- Person X ID: ID1= 123
- Person Y ID: ID2 = 250
- IDTAG = predefined formula in programming to calculate IDTAG from ID
- Data = temperature readings (2 bytes)
- Sum = 1+2+3=06 (ID1), Sum= 2+5+0=07(ID2)

There are various IR protocols which can be used for coding data on carrier frequency like RC5, RC6, NEC, Sharp, Sony, JVC etc. We have used Sony protocol (which uses pulse width coding scheme) available in the arduino IR remote library in this project. The sensed temperature data along with the unique IR tags for different persons is sent on the same 40KHZ frequency as used by TV remote control IR LED's to keep the circuitry as simple as possible and cheap.

3.4 Receiver

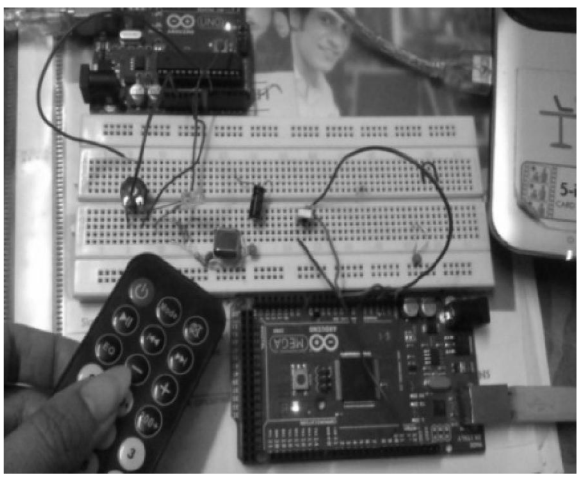
An OW receiver mainly comprises of an optical system which gathers and combine the arriving radiation, an optical filter to discard ambient illumination, and a photo detector to transform radiation to photocurrent. There is a need of additional amplification, filtering and data retrieval for the refinement of the detection process.

The receiver used in our project is demodulated at 40 KHz frequency. The receiver consists of built in demodulator and is directly connected to another microcontroller Arduino Mega 2560 which not only decodes the incoming information i.e. temperature data but also rejects the other signals coming from sources by programming techniques. The microcontroller is programmed in such a way that it extracts the tags from the received data, if the tag is matched with the person unique ID and its sum, only then the information is processed otherwise ignored. Various experiments were performed to see the effect that either the receiver is capable of rejecting unwanted signals or not, in the presence of TV and AC remote signals and process temperature data as shown in Figs. 3-4.

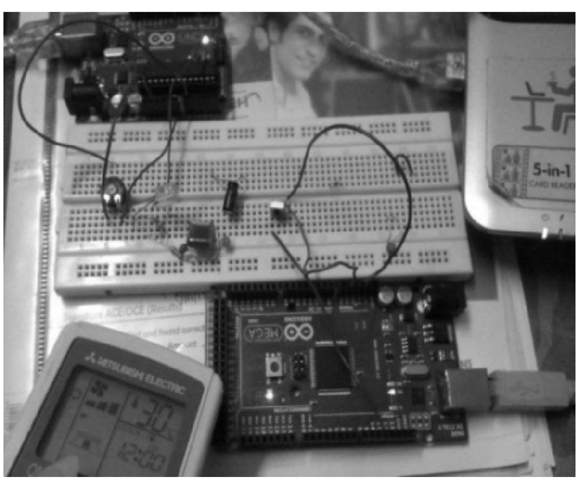
TABLE 3. DATA PACKET FOR TEMPERATURE SENSOR READINGS

ID	ID Tag (Hex)	Sensor Data (Byte-2)	Sensor Data (Byte-1)	Sum
ID1	46	X	X	06
ID2	9C	X	X	07
Packet Byte No.	1	2	3	4

Snapshot from Arduino serial monitor in Fig. 4 shows the detection of remote control codes 32 bit data along with temperature data in Hex Format (as well as in degree Centigrade and Fahrenheit). First medium level of IR tags strength was tested by using less number of bits for the tags, though the rejection of unwanted patterns was achieved but it resulted in the detection of remote control codes at some occurrences of matched patterns. This detection was further improved by implementing higher level of IR Tag strength algorithm through programming as described in Table 3 which uses IDTAG as well as SUM in the packet; this eliminates the detection of remote codes at any occurrence.



(a.) USING TV/DVD REMOTE



(b). USING AC REMOTE
FIG. 3. HARDWARE SETUP FOR CHECKING EFFECTS OF INTERFERENCE

4. RESULTS AND OBSERVATION

The effects of line of sight, acceptance angle, distance between transmitter and receiver, role of obstacle between transmitter and receiver, impact of opacity of obstacle were also observed. It is observed that our system was capable of transmitting the data up to 3-4 meters with accuracy. The data is received correctly when LOS is maintained. The data is accurately received even if the transmitter is displaced 30-40 degrees from the receiver. The data gets corrupted if the distance between transmitter and receiver is increased from 4 meters or the transmitter gets away from LOS beyond 40 degrees from receiver. The data gets completely blocked if any obstacle is placed in between the transmitter and receiver. Fig. 5(a-d) illustrates these experiments and observations.

5. CONCLUSIONS

In this project feasibility of IR transmission and Reception is tested only for temperature readings. The transmission is tested for two subjects though have the capability to accommodate 256 subjects which can further be extended by modifying hardware and programming techniques. The transceiver design is tested in presence of natural light, fluorescent light and other IR signals at room temperature. The transmission is done using Sony protocol which uses pulse length encoding at 40 KHz, WBAN is attracting physicians to monitor the chronic patients. Particularly, who need immediate watch/monitoring to Blood Sugar, Pressure and Pulse, etc.

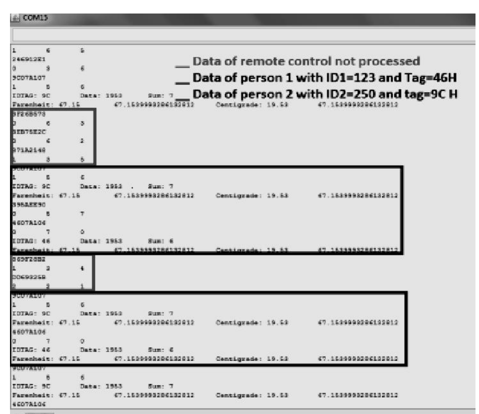
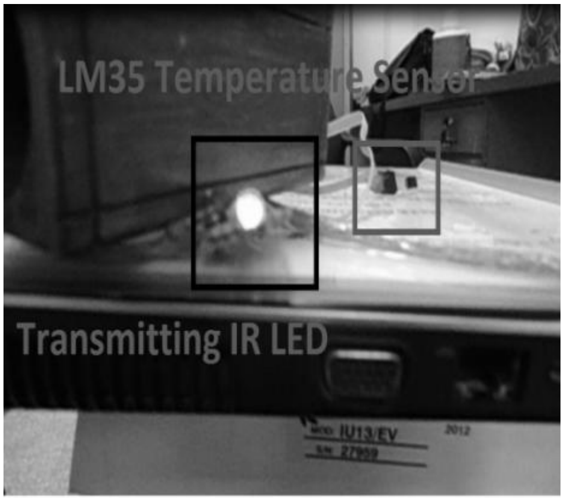
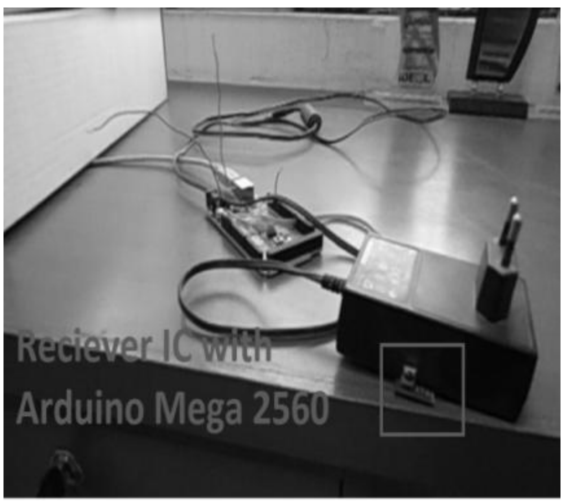


FIG. 4. RECIEVER'S RESPONSE IN PRESENCE OF INTERFERENCE SIGNALS WHEN ID1 OR ID2 AND REMOTE CONTROL TRANSMITTING THE DATA

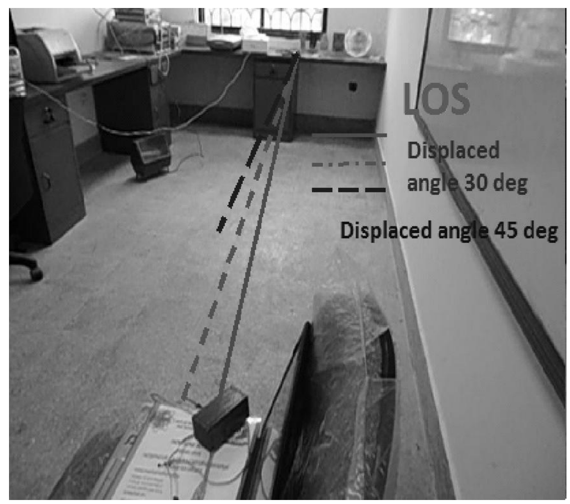


(a) IR LED TRANSMITTING TEMPERATURE DATA

(b) ARDUINO UNO WITH IR LED AND TEMPERATURE SENSOR



(c) TV REMOTE RECEIVER IC WITH ARDUINO MEGA 2560



(d) HARDWARE SETUP FOR TESTING LOS, FOV AND DATA ACCURACY OF IR TRANSMITTER AND RECEIVER

FIG. 5. HARDWARE SETUP FOR EXPERIMENTS AND OBSERVATION

The system can be improved for high data rate applications where needed simply by replacing the IR transmitter and IR receiver that supports high data rates. This system can also be extended to accommodate more number of sensors and tested for their reliable transmission, by suitable modifications in hardware and software design. There are various other protocols with different encoding schemes and modulation schemes at different carrier frequencies within range of 33-50 kHz which can also be tested and compared for best results. Only LOS link is tested in this system and it can be tested for other configurations as well.

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