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Green Environment Monitoring System (Gems) for Industries using Li-Fi Technology

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Abstract

Objective: This work assures to design a green environment monitoring system for industries using Li-Fi technology to provide secured communication, high data rate transfer and pollution free environment. **Methods:** The LPC 2148 microcontroller with ARM 7 core is chosen for implementation. Light-emitting diodes are used as the source for data transmission and they are preferred as they have a longer life-time. Different sensors are deployed to monitor various parameters namely temperature, Gas and light intensity in an industrial environment and these sensors transmit the sensed information using Li-Fi technology in terms of flickering of LEDs. Linear quadratic estimation algorithm is implemented to improve the accuracy of sensor values. **Findings:** The proposed system is implemented in ARM 7 Core (LPC2148) that consumes less power. The designed system provides communication at the rate of 1.5 Mb/s over a distance of 5 meters and they are free from electromagnetic interference. They are not affected by artificial or natural light sources. **Improvement/Applications:** The implementation of Linear Quadratic estimator improved the accuracy of sensor output values. This technology is eco-friendly and the working atmosphere is conserved thereby ensuring a green environment. The sensors used in industrial applications communicate with low cost and also in a secured manner.

Keywords: Industrial Environment Monitoring, Li-Fi, Light Emitting Diodes, Photo Detectors, Visible Light Communication

1. Introduction

The Light-Fidelity (Li-Fi) technology was invented and coined by Harald Haas. Li-Fi is viewed as the future of wireless communication. Li-Fi uses light waves for data transmission Light-Fidelity is gaining its popularity due to its wide deployment, eco-friendliness and available bandwidth in the spectrum. LiFi provides better security than orthodox Wireless Fidelity (Wi-Fi) communication. This makes Li-Fi difficult for the hackers to infiltrate. Li-Fi is a full duplex communication using light waves. Li-Fi has certain constraints such as it cannot penetrate walls and ceilings which limit it communication range. The light intensity of natural and artificial light sources affects the receiver and the communication might be blocked. The saturation must be prevented and robustness to noise must be improved for better communication. There are certain constraints of optical communication the light intensity should be in acceptable range. It should not affect human vision[1]. The flow of electrons, connect number, the rate of sampling, and sensors signal types are habitually limited by the equipment in the Internet of Things (IoT) scenario, every sensor connected to the equipment is needed to write complex and large amount of program code for data collection. A new idea is put forward for a smart sensor interface design that is reconfigurable for industrial Wireless Sensor Networks in Internet Of Things scenario, in which Complex Programmable Logic Device (CPLD) is chosen as the main controller. Because of its ability to read data in parallel and in real time with great speed on many different sensor data. The intelligent sensor interface specification IEEE 1451.2 is chosen for the design. The reconfigurable smart sensor interface device is explained in this work. At last, by monitoring of water in real time industrial scenario using Internet of Things as a prototype model, we assured that the setup achieved satisfactory results in real time application[2]. The spectrum demand

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has forced scientist to look for another source to traditional radio frequency communication. Optical Wireless Communications (OWC), and especially in Visible Light Communications (VLC), have been found as assuring technologies. The habitually used device for high speed data transfer is Photodetectors (PD). Because of their capacity to provide greater speed linear photodetection at feasible levels of illumination. The demerit of such photodetectors is that they need exterior power to work. This demerit will be overwhelmed by implementing a solar panel in the location of the photodetector. The solar panel can alter the light signal to an electrical signal, with no need of an exterior power supply. The usage of a solar panel as an alternative to traditional photodetectors. Further simplifies the receiver circuitry by eradicating the need for a trans-impedance amplifier. A unique receiver for optical unwired communication implementing a solar panel as the photodetector was put forward. The solar panel can change the modulated light into an electrical signal without the requirement for a power source. Harvesting of energy and communication can be recognized at the same time by this methodology[3]. Electromagnetic compatibility problems are still present among other users when the number of users increases in in-flight internet usage. Optical wireless communication is a method of decreasing the whole setup weight induced by the wiring of every single passenger seat. Unwired optical connectivity provides few merits on a cabin of the plane because it has no Electro Magnetic (EM) issues. A Cost effective Visible Light Communication setup is put forward for the in-flight application. Complete unwired optical connectivity is acquired by using a Visible Light Communication setup for the download and an Infra Red (IR) setup for the upload. The designed adapter for the laptop of the passenger provides a flexible solution using the Ethernet port no need of installation of an additional driver. The work at the MAC layer also provides complete transparency to the user applications. The setup can be quickly deployed and gives personalized in-flight entertainment and services by wireless media. This technology need not get affected or generate interference with radio. Baud rates can be improved at a remarkable rate using RGB LEDs lamps and ASIC devices. The protocol needs on the light channel are also decreased because each lamp-photodiode couple serves as the access point that is dedicated for every singular seat[4]. The overhead of handover must be taken into account in designing Load Balancing (LB) model for networks that are hybrid. Handover in traditional mobile radio frequency networks generated at the time of users acquiring a less Signal-to-Noise Ratio (SNR) from the served Base Station (BS) than that from other (BS). Anyway, in an indoor network that is hybrid, the problem of stability must be considered as a handover may tempt next handovers. Consider an example, if a user is moved from the Light-Fidelity layer to the Wireless-Fidelity layer, it will raise the load in the corresponding Wireless-Fidelity cell. Remaining users are served by this Wi-Fi Access Points (AP) might need to be moved to nearby Wireless-Fidelity access points, or have decreased the rate of data transfer. Another reason is because of the reduction in load of Light-Fidelity at to cell, resources are removed to improve the rate of data transfer for users already present. The goal is to design Load Balancing model that assure high throughput from the user, decreased overhead during handover, fair and stable in a Light-Fi/Wi-Fi setup that is hybrid, A Dynamic LB model in a Light-Fidelity/Wireless-Fidelity hybrid network is put forward, where the overhead of handover is taken into account. By analyzing the areas of service provided by the Li-Fi access points, the throughput performance of the system which was hybrid was studied theoretically. The effects of the handover overhead on locations of handover and throughput of the user are simulated and discussed[5]. Reduction of power consumption of nodes by designing a sensor array for monitoring workplace environment in industrial installation. The unwired realization of sensing system and its analyzing of the performance of sensing, in the lab environment, for the viewing of particular volatile organic compounds available in printed flexing packaging industries is shown. The unwired sensing system was checked in laboratory environment upon exposure to particular analyses of interest simulating the work area surrounding of the application that is real. The output depicted that the setup for sensing is characterized by nice performance for sensing with greater repeatability and steadiness in a longer time period. In addition, the calculated limit of detection values by extrapolation for EtOAc vapor are 45 and 88 ppm for PBMA and PDMS (RTV615) sensors coated correspondingly, which are under consideration less than the respective TWA value (400 ppm). Further PCA was used for data post-processing. The values of PCA raises in linear with both

Volatile Organic Compounds and concentration of humidity but are located at various PCA score area. Because of this characteristic, the separation b/w values respective to gaseous environments of various composition and various concentration can be accomplished. The work concludes, the unwired sensing system, because of its less consumption of power, has the ability to be applied for monitoring unattended industrial environments in real time[6]. The available model restricts the allocation of users to a specific cluster color. Thus, it is not appropriate for home environments that are smart where mobile data users are often expected. Hence, there is a requirement for complete two ways Visible Light Communication systems for applications in the home environment. A unique CCMA based Visible Light Communication model to enable more than a user communication in both directions in an indoor environment for smart home technologies is put forward. The simulation output depicted that the idea put forward is robust and efficient in an environment that is indoor with multiple users in terms of data rates and BER. This model can be taken into account as attractive to envision a practical high-speed many users bidirectional Visible Light Communication for economical implementation in upcoming applications in the home that are smart to support a number of users in the Visible Light Communication scenario[7]. Background ambient light affects VLC system performance in a mobile phone CMOS camera. Visible light communication using differential signaling and spread spectrum modulation is recognized by a mobile-phone camera is put forward and shown for the first time to give greater immunity to ambient light interference in the background. Results depicted that the system put forward has gains of 6-db when compared with the On Off Keying modulation method under ambient light in the background of3000lux. The ambient light that is direct to a mobile-phone camera is 520lux.BER<10^{12} was obtained in the measurement[8]. The sharing of the similar frequency band between Wifi and Zigbee caused packet loss and delay in transmission when they use the same channel for communication. The effect of interference of the Wireless-Fidelity signals on the channels of zigbee was investigated depending on experiments in real time under various wireless environments that are noisy. The interference level distribution and Packet Error Rate (PER) are used as signs to calculate the sixteen Zigbee channels in the 2.4 Giga HertzISM band[9]. Frequency overlap produces interference and affects reliability in communication. A new methodology BuzzBuzz is put forward to overcome interference of Wireless-Fidelity by the way of header and redundancy of payload Multiple headers provides header redundancy providing zigbee motes many chances to analyze packets that are incoming. Then, Tiny RS, (Reed Solomon) complete featured library for devices with limited resources, helps to decode packet payload which is polluted. BuzzBuzz is an MAC layer solution that enables 15.4 nodes to exist with Wireless Fidelity networks. BuzzBuzz uses Multiple headers and Forward Error Correction to handle the loss of packets because of 802.11 interference. Tiny RS is implemented to depict that a complete-featured Forward Error Correction library is possible on nodes that are resource constraint. It is observed that BuzzBuzz raises the reception rate of the packet on a 57-node test bed by 70% while at the same time decreasing the number of transmissions by a factor of three[10]. Sensors for industrial based application are discussed in the work[2] and[6]. The visible light communication in various applications areas such as solar panel receiver for optical communication, Visible light Communication based in-flight entertainment etc., are discussed in[3-7] and[8]. Wi-Fi and Zigbee interference issues are discussed in the work[9,10] Li-fi for the industrial environment has not been discussed yet up to best of author's knowledge. So we propose a Li-Fi based communication for industrial environment monitoring application.

2. Design of the Proposed System

Figure 1 provides the block diagram of the proposed system. The goal of the system put forward is to have an industrial environment monitoring system that is less polluted and eco-friendly. The ARM7 core LPC2148 is chosen as the microcontroller because it consumes less power. The sensors are connected to the corresponding Analog to Digital Converter (ADC) channels in LPC 2148 microcontroller. The analog values of Temperature, Gas, and Light intensity in the environment are acquired by the sensors. The analog values from the sensors are converted to digital by on chip analog to digital converter available in the LPC2148 microcontroller. The LED lamp is used as the transmitter in Li-Fi communication. The light from the LED lamp is received by a photodetector. The Light Emitting Diode as a transmitting source does not cause any electromagnetic interference. This makes it suitable for industrial environment monitoring. When the threshold values of the sensors exceed a warning alarm is produced to alert the employees to evacuate. The Li-Fi solves the traditional issues in radio frequency communication such as Wi-Fi and Zigbee interference in industrial monitoring applications. It also solves the traditional issues such as zigbee to zigbee interference in industrial environment monitoring. It is more secure than RF communication which makes it difficult for the hackers to infiltrate. It eliminates health hazards caused to the humans and the environment by traditional radio frequency communication. Thus making the environment greener and safer for the survival of living organisms.

3. Implementation of Algorithm

In order to have the effective values from the sensors linear quadratic estimation technique is used. This makes the effective decision making from the fusion of sensors. The values from the sensors are given as input to the Linear quadratic variables, the Linear quadratic estimation process for the sensor variables is done by three steps they are,

Linear quadratic estimation process for each time step t.

The equation 1,2 which predicts the next state from the observed state and present state, so the variation of values will not vary under normal condition.

$$x(t) = F * X(t-1) + B*u \quad (1)$$

$$P(t) = F * P(t-1) + F^t + Q \quad (2)$$

Equation 3 gives the overall gain for the process that makes the difference from the normal sensor values and the processed value

$$K = P(t) *H^t + (H * P(t) * H^t +R) \quad (3)$$

Equation 4 and 5 which gives the absolute result for the decision making process to produce an warning alarm, based on the values from the sensor.

$$X(t) = x(t) + K * (measurement(t) – H * x(t)) \quad (4)$$

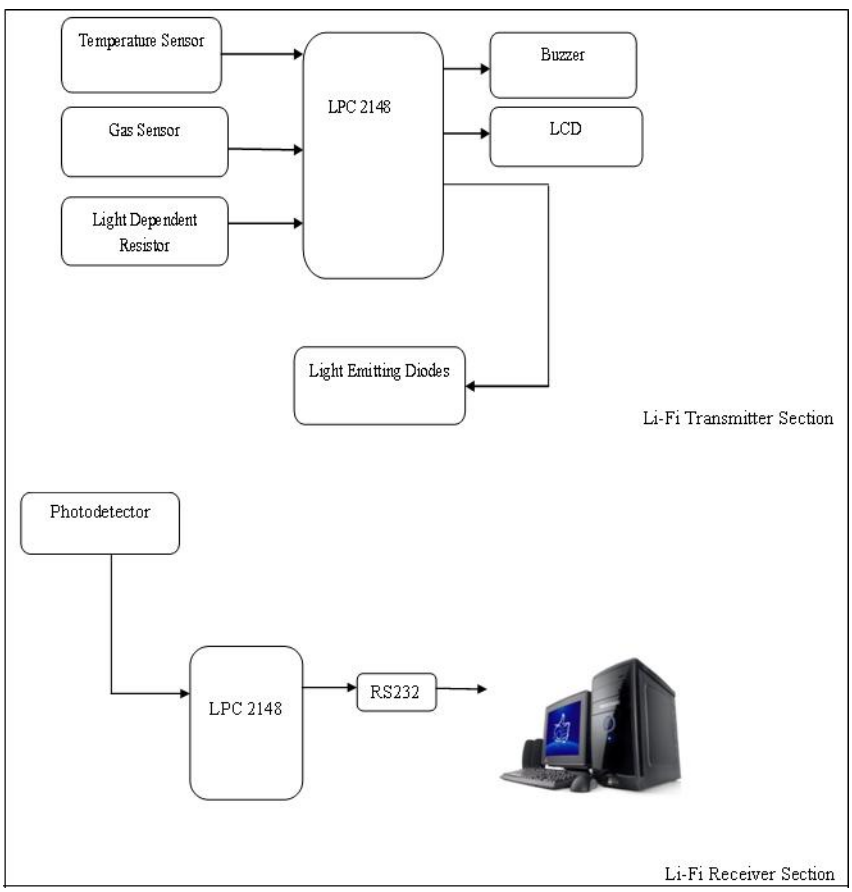

Figure 1. Block diagram of the proposed system.

P(t) = (I – K * H) * P(t) (5)

State assumptions form the proposed model,
X(t) = F * x(t-1) + B * u + Process noise
z(t) = H * x(t) + Observation noise

Here in this above equations, x(t) = sensor output voltage.

In order to have the accurate values from the sensor this process is done, since without this process the values from the sensor varies abruptly, so to maintain the constant improvement the sensor values are given to Linear quadratic estimation process, for this F = 1, since there is no control input to the system B = 0, output voltage will be available when H = 1, Process noise covariance is Q, Observation noise variance is R. here we are assuming process noise variance is low and it is set to Q = 1e-9. Substitute the values of H=1, F=1, I=1, B=0, Q= 1e-9, R=1.124-5 to the above equations 1,2,3,4,5 we get the final result for the Linear quadratic estimation process and is shown,

- x(t) = F * X(t-1)
- P(t) = P(t-1) + 1e-9
- K = P(t) + (P(t) +1.124-5)
- P(t) = (I – K) * P(t)
- X(t) = x(t) + K * (measurement(t) –x(t)), which is the Linear quadratic estimator process output.

Figure 2 shows the performance comparison between Normal sensor values and Sensor values processed using linear quadratic estimation algorithm.

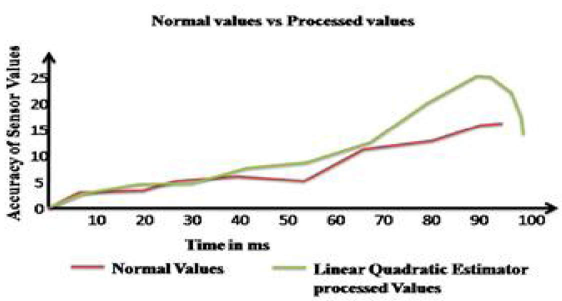

Figure 2. Comparison between normal values and processed values using linear quadratic estimation.

4. Experiment and Results

The Li-Fi transmitter setup with the LPC2148 core, Temperature sensor, Light Dependent Resistor (LDR), Gas sensors and Led transmitter are depicted in the Figure 3. The values of sensors and LDR are displayed on the LCD. The Li-Fi receiver setup with photodetector and a laptop is shown in the Figure 4.The experimental results showed that a distance of 10 meters can be achieved at a data rate of 1.5 Megabits per second and the data transmission is not affected by natural and artificial light sources. The Lab view integrated development environment is used to depict graphical output of sensor values The output values of sensors are depicted in the Lab view IDE in Figure 5.

Figure 3. Li-Fi transmitter.

Figure 4. Li-Fi receiver.

Figure 5. Labview output.

5. Conclusion and Future work

The proposed system is implemented in ARM 7 Core (LPC2148) that consumes less power. The designed system provides communication at the rate of 1.5 Mb/s over a distance of 5 meters and they are free from electromagnetic interference. They are not affected by artificial or natural light sources. The implementation of Linear Quadratic estimator improved the accuracy of sensor output values. The application is suitable for radio frequency sensitive industries such as nuclear power plants. Li-Fi is secured and free from pollution. The Li-Fi provides higher data rate for communication. The bandwidth of data transmission can be varied at ease than orthodox wireless networks. Cameras can be integrated with the monitoring sensors and information can be transferred through the internet in future to provide warning and alert signals about a cause of accidents in industries during an emergency.

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