Design and Development of a Structural Health Monitoring System Using Light Fidelity

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***Abstract* - Visible light communication means, communication from one point to another using light. Visible light communication is an area which is yet to be fully explored. The advantage of VLC is that there is no need to bother about the spectrum as the entire visible communication range can be effectively utilized for communication. In areas like that of a bridge, where the monitoring of its health is a major concern due to various natural changes happening, abnormal vehicle population, improper construction of the bridge etc, the importance of health monitoring is necessary for the safety of human beings. It is with this intention; this idea is introduced which will ease the health monitoring with no additional expense of its own. The health monitoring of the bridge is done based on the various parameters like strain/stress induced on the structure, wind speed, temperature and condition of the road. All this information can be obtained by using a single mote(node) that consists of several sensors which can sense the required parameters. The next step is to send the sensed data to the desired location. The current mechanism involves sensing data and transmitting it wirelessly using utilizing the frequency spectrum. The problem of sending in that way is the availability of the spectrum and the loss incurred if the base stations are far from each other. This issue can be resolved by sending the data wirelessly by using light. Flickering can be used to send the data by means of LED arrays. If the LED is ON that indicates a 1 and if LED is OFF and this indicates data is 0. By proper flickering of LED and LED arrays transmission can be done between two motes if there is a light transmitting and receiving devices at each mote. The mote can be used to send the sensed data by itself or can be used to mirror or transfer the data it receives from other motes to some other motes or to the desired location.**

Key words: Structural health monitoring, mote, LED, visible light communication

I. INTRODUCTION

As the world move forward with time; roads, bridges, flyovers etc. will play a vital role in expanding the progress of a country to many folds. It is very essential to have a system to monitor the health of bridges once built and still in use. Health monitoring of bridges is a serious area of concern and cannot be ignored at any level failing which will cause the loss of many lives. Recent advancement in technologies has made it possible, the fact that the monitoring can be done at a different location far away from the bridge. As many countries are embracing these new technologies, it's always better to improvise the existing technologies and move forward. Most of the current structural monitoring system involves man intervention and it is difficult to monitor these as life moves on. The introduction of wireless sensors and modules made the task much easier, but the usage of RF spectrum was still the major concern. The security, maintenance and installation of such modules are still costly.

In this paper, a structural health monitoring using visible light communication is proposed. The main challenge we face today is the limitation of frequency spectrum for communication. Normally we utilize microwave signals for communication. But the problem is spectrum is limited which in turn restricts the communication distance. The Visible light communication uses visible light spectrum from 380 nm to 750 nm for communication purpose. Visible light communication involves LEDS and LASERs as light sources. But LEDS are used because of their better efficiency, high flickering rate, longer life span, and reduced cost features [2]. The transit time of LED is very short for switching ON and switching OFF the LED and this process is called flickering. Normally we use white LEDs for communication purpose. The challenges when we use visible light communication are the limitation of distance between transmitter and receiver. Line of Sight is mandatory between the source and receiver. The distance of communication is limited as its VLC and the data rate will be low as LEDs are used for communications which are the demerits of using visible light communication. The availability of the spectrum is the main advantage while using visible light communication. As it is intended for short rate communication only, the data rate tends to slow down if the distance between the transmitter and receiver increases [3]. The data rate can be as high as that of Gbps if the transmitter and receiver are only few meters apart. Any kind of interference will stop/ pause the communication.

The main challenge we face today is the limitation of frequency spectrum for communication. Normally we utilize microwave signals for communication. But the problem is spectrum is limited which in turn restricts the communication. The main components of the visible light communication system are,

1) A high brightness white LED, which would act as a transmitter

2) A silicon photodiode, which shows good response to visible wavelength region, as a receiving element

The LED radiance can be used as a communication medium by modulating the LED light with data signal. The flickering rates of LEDs is so fast that it appears constant to human eye. Data rates greater than of 100Mbps is possible using high speed LEDs [1]. The Visible light communication uses visible light spectrum from 380 nm to 750 nm for communication purpose. Visible communication involves LEDS and LASERs as light sources. But LEDs are used because of their better efficiency, high flickering rate, longer life span, and reduced cost features. The transit time of LED is very short for switching ON and switching OFF the LED and this process is called flickering. Normally we use white LEDs for communication purpose. The challenges when we use visible light communication are the limitation of distance between transmitter and receiver. Line of Sight is mandatory between the source and receiver. The distance of communication is limited as its VLC and the data rate will be low because LEDs are used for communications which are the demerits of using visible light communication. The availability of the spectrum is the main advantage while using visible light communication. As it is intended for short rate communication only, the data rate tends to slow down if the distance between the transmitter and receiver increases. The data rate can be as high as that of Gbps if the transmitter and receiver are only few meters apart. Any kind of interference will stop/ pause the communication.

II. Proposed Design

The health monitoring of the bridge is the process by which the life span of the bridge can be determined by constant analysis and checking. To make it possible, a set of sensors are deployed and assembled in a node which is capable of sensing as well as transmitting data from other nodes. The node consists of several sensors that can help in determining the health of the bridge and can give a brief view of the deterioration effects and this will put light in to an overall life span of the bridge. The sensors which can be used in the nodes are load cell, accelerometers, strain gauges, wind sensors and temperature sensors. Apart from this, cameras can be installed to check the displacement between plates of the bridge. The sensor data can be converted to digital signals with the help of a micro controller and then it can be converted into light. Binary signal one can be represented by LIGHT ON and binary signal 0 can be represented by LIGHT OFF. So, by proper flickering of the LED light, the digital data can be communicated in binary format using light as the source of communication. By modulating the LED flickering at a high rate, high speed communication is possible between transmitter and receiver. This modulation mechanism is done by the microcontroller with a driving circuit which will drive the LED module with sufficient current based on the digital input. So, the information is passed from transmitter and the information will reach the receiver in the form of light. The transmission medium can be either air or water. In case of water, the distance is further limited and so is the data rate for communication. In the receiver side, different photo diodes like avalanche and PIN diodes can be used which have the ability to convert the received light energy to electric pulses. The corresponding digital information can be encoded from the received light signal and can be processed for further signal processing and analysis of information. It has been observed that PIN photo diode deliver better performance in visible light communication and can be used for the proposed design. PIC 16 F 877 A can be used a microcontroller for the design. There is presence of in-built ADC inside the PIC microcontroller.

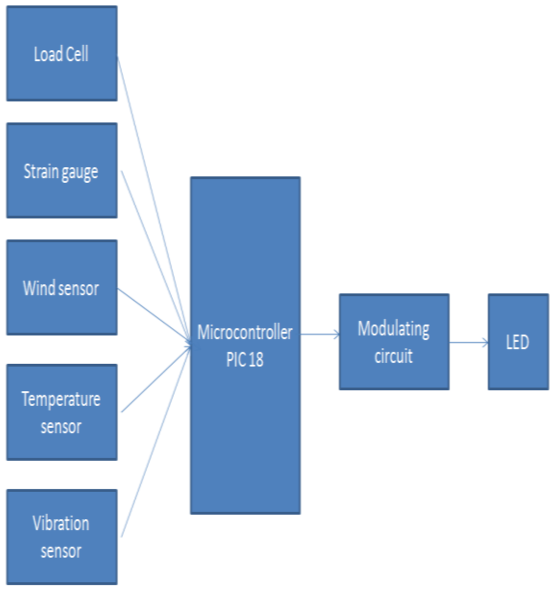

Fig 1. Block Diagram of Transmitter module

III IMPLEMENTATION

As it can be observed from the block diagram, many sensors can form a node and this node can be connected to microcontroller after enhancing the signal parameters using a signal conditioning circuit. PIC 18 has built in ADC which will convert the analog signals from sensors to digital values. The values obtained as 1s and 0 s can be sent to LED array after modulating it properly. In this section, the values in digital form will be fed to the LEDs by proper modulation and LEDs will be generating a light OFF condition if a 0 is to be transmitted and a light ON condition when a 1 is to be transmitted. This light passes through the medium and reaches the receiver. At the receiver, a photodiode is kept to accept the incoming light and to process it to generate the digital streams from the incoming light. The receiver module will have Photo diode, demodulating circuit and a microcontroller signal processing mechanism to retrieve the signal transmitted from the transmitter.

III.1) Transmitter section

Sensor module

The role of sensor nodes can be classified into two. One is to sense the parameter to be sensed. The second role is to transmit the data in the form of light. To facilitate the process of sensing different types of sensors can be deployed. The sensors that can be used to improve the monitoring of a bridge are load cell, accelerometers, strain gauges and wind sensors. These sensors sense the parametric values and these values will be amplified using a signal conditioning circuit and will be fed in to the ADC port of PIC microcontroller. After converting into binary data, it will be fed into modulating circuit which will modulate the incoming bitstream into light, by means of LEDs.

PIC 16 F 877 A

PIC 16 F 877 A uses RISC architecture which means the number of instructions to learn is relatively less even though some of them are complex. 35 instructions are present in PIC 16. It uses Harvard architecture i.e. separate memory for storing data and program. It has got some unique features like built in flash memory, EEPROM data memory with 5 digital ports and 15 different interrupts to pause the microcontroller at any point of time. PIC 16 is rich with 3 hardware timers built in USART, Analog comparators and one in built 10-bit ADC module which can be effectively used for the proposed design.

Light Emitting Diode (LED)

Light emitting diodes are the light sources that are used for communication in the proposed design. White LEDS are used because of its faster flickering abilities, response time and cost-effective feature [3]. The LED will produce light when a binary 1 is fed into the input of LED and it turns off when a 0 is fed into the input of LED. So, by constantly modulating the light source with binary data stream, a generation of data can be realized by means of light. THE LEDs are to be placed at line of sight for the proper communication of data. This light will travel through the medium and will reach the receiver section for further processing.

III .2) Receiver Section

The receiver module will have Photo diode, demodulating circuit and a microcontroller signal processing mechanism to retrieve the signal transmitted from the transmitter. The photo diode used is PIN photo diode and it can convert the light signal into corresponding electric pulses. The demodulating circuit will convert the digital data stream into binary bits and this can be given to processing unit to retrieve signal from the received signal. Once we got the data we require, the following flow chart can be followed to analyse the bridge under question. The information about the damage and wear and tear will be obtained from different sensor values and the accelerometer and wind sensors will help in predicting the life time of a bridge along with the other sensors in use.

Photodiode& Microcontroller

A PIN photodiode is used to convert the incoming light stream into corresponding electrical parameters. With the help of microcontrollers in the receiver section, the data can be either transmitted to the next node to transfer the received data stream or can be made to store the data at the final node for final processing of the data. The data will be processed and analysed at data processing unit.

Data Acquisition Unit (DAU)

The processing and analysing of received data will be held at data acquisition Unit. The threshold values to determine the stage of bridges will be preloaded in the database of the DAU and based on the graphs and analysis we can get an overview of the present status of the bridge and make a forecast on how long the bridge will survive with existing conditions.

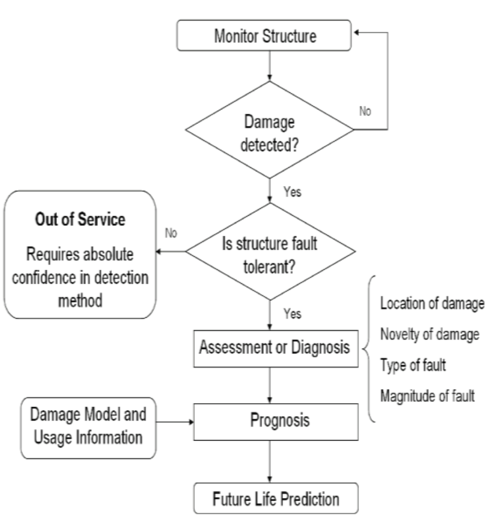

Fig 2. Flow chart for the analysis of the bridge

IV. CHALLENGES AND DISCUSSIONS

The distance of communication is limited as its VLC and the data rate will be low because LEDs are used for communications which are the demerits of using visible light communication. The availability of the spectrum is the main advantage while using visible light communication. The main challenge in executing the proposed system is the intrusion due to other lighting sources. Other limiting factor can be the distance between the sender and receiver will be near to of 65 cm which is not a good outcome. Even then the problem can be reduced by installing more sensor nodes and line of sight can be maintained between them. Illumination LEDs can be made into transmitting sources and it will light up the bridge at the same time, take part in diagnosing the bridge's health parameters. Based on the decisions made with the flow chart, it can be concluded whether the bridge needs repair at present or not. If a damage is detected, the bridge should not be used and it should be serviced and repaired [5],[6]. Such information about the bridge health will be available through our proposed design as the sensors will be able to give the correct data about the conditions a bridge is undergoing.

V CONCLUSION & FUTURE SCOPE

Eco friendly transmission is very much feasible through light fidelity. The white LEDs are used for transmission of data. With advanced light sources coming up in recent times, these white LEDs can be replaced by better light sources and photodiodes can be made with fine doping in order to get a better performance, faster data rate and higher transmission distance. With the advances in technologies, internet streaming can also be made possible for travellers passing through the bridge and a warning system can also be added if the bridge starts to deteriorate. This information will be available from the DAU. So, by utilizing the methods of proposed design, an ideal system can be implemented that can properly monitor the health parameters of a bridge and can warn the people if there are some problems that are to be addressed and thereby can save many lives.

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