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Infrastructure Health Monitoring

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ABSTRACT

In this paper of measurement system for measuring dynamic acceleration of infrastructure remotely using WI-FI environment. This measurement is critical to the vibration-based method for infrastructure health monitoring. Design considerations of accelerometer integrated with embedded system is implemented. Measurement results of the system for a structural specimen have shown that it is capable of acquiring data which provides the information of natural frequency of the structural specimen. Moreover, the system can distinctively identify the state changes of the structural specimen using MEMs , Temperature, Humidity sensors.

Keywords: MEMS sensor; Infrastructure health; SHM Structural health monitoring; DHT 11; insert

I. INTRODUCTION

The design, construction and fabrication of smart structures are one of the extreme challenges to engineering researchers today. Because they form the essence of system intelligence, one of the cores of smart structures technology centers around innovative sensors and sensor systems. The Structural health monitoring (SHM) indicates one of the primary applications for new-sensor technologies. Indeed, much attention has been focused in recent years on the declining state of the aging infrastructure in the U.S., as well as to the limitation of their responses during extreme events (such as wind and earthquakes). These concerns not only apply to all civil engineering structures, like the nation's bridges, highways, and buildings, but also to other types of structures, such as the aging fleet of aircraft currently in use by domestic and foreign airlines. The ability to continuously monitor the integrity of structures in real-time can provide for increased safety to the public, particularly for the aging structures in widespread use today. The ability to detect damage at an early stage can reduce the costs and down-time associated with repair of critical damage. Predicting and/or observing the onset of dangerous structural behavior, like flutter in bridges, can allow for advance warning of such comportment and commencement of removal of the structure from service for the protection of human life. In addition to monitoring long term degradation, assessment of structural integrity after catastrophic events, such as earthquakes, hurricanes, tornados, or fires, is vital.

These assessments may be a large expense (both in money and time), same as was seen after the 1994 Northridge earthquake with the numerous buildings that needed to have their moment-resisting connections inspected. Additionally, structures internally, but not obviously, damaged in an earthquake may be in great danger of collapse during aftershocks; structural integrity assessment can help to identify such structures to enable evacuation of building contents and occupants just prior to aftershocks. Furthermore, after natural disasters, it is imperative that emergency facilities and evacuation routes, including bridges and highways, be assessed for safety. The need for an effective SHM is essential, for primary targets such as systems being to enhance safety and reliability and to reduce maintenance and inspection costs. To efficaciously investigate both local and global damage, a dense array of sensors is envisioned for large civil engineering structures. Such a complex and dense array should be designed to be scalable, which shows that the system performance does not degrade substantially or at all as the number of components increases. In the conventional approach using wired sensors, the shear number of accompanying wires, fiber optic cables, or other physical transmission medium may be prohibitive, particularly for structures such as long-span bridges or tall buildings. Consequently, the global communication in a wireless manner that will facilitate cheap, densely distributed sensing has been investigated. Rapid advances in sensors, wireless communication, Micro Electro Mechanical Systems (MEMS), and information technologies have the potential to significantly impact SHM.

To assist in dealing with the large amount of data that is generated by a monitoring system, on-board processing at the sensor allows a portion of the computation to be done locally on the sensor's embedded microprocessor. Such an approach provides for an adaptable, smart sensor, with self diagnosis and self-calibration capabilities, thus reducing that amount of information that needs to be transmitted over the network. Kiremidjian [2] indicated out that pushing computation forward and data acquisition is fundamental to smart sensing and monitoring systems, but represents a radical departure from the conventional instrumentation design and computational strategies for monitoring civil structures. Following an introduction to smart sensing, some of the opportunities, as well as the challenges offered by this new technology, are presented.

II. LITERATURE REVIEW

A. Paper survey

In paper 'An Overview on the Applications of Structural Health Monitoring Using Wireless Sensor Networks in Bridge Engineering' by Ramzi Shaladi, Faesal Alatshan, and Chunhui Yang ,published in Int'l Conf. on Advances in Science, Engg., Technology & Natural Resources (ICASETNR-15) Aug. 27-28, 2015 ,it states that " In this paper, we aim to highlight on the latest technologies and developments in the field of Structural health monitoring (SHM) using Wireless sensor networks (WSNs) in bridge engineering. The need for SHM has become inevitable for broad engineering fields including civil engineering sector. The WSN - Wireless sensor network technology has drawn tremendous research interests, which can powerfully improve the versatility and flexibility of SHM by implementing WSN as a vital tool for practical applications in bridge and building. The attention for WSNs has been greatly increased due to their accuracy, low-cost installation, low-cost sensing and capability to process data on-board and thus there is trend to apply the WSN technology to take place of the traditional wired monitoring systems. Even though, successful SHM applications have been done on some critical civil structures using the WSN technology at the Lab and the field, it is still very limited to be employed for practical implementation in full-scale structures. Therefore, ongoing WSNs applications on full-scale civil structures are still needed to be conducted beside the lab evaluation to finally achieve the desired objective which is the SHM. "[3].

In paper 'Smart sensing technology for structural health monitoring' by Billie F. SPENCER Jr., Manuel RUIZ-SANDOVAL, Narito KURATA, published in 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada August 1-6, 2004 ,Paper No. 1791,it states that " "Smart" sensors with embedded microprocessors and wireless communication links have the potential to fundamentally change the way civil infrastructure systems are monitored, controlled, and maintained. Indeed, a 2002 National Research Council Report noted that the use of networked systems of embedded computers and sensors throughout society could well dwarf all previous milestones in the information revolution. In fact a framework still does not available that can avail the distributed computing paradigm offered by smart sensors to be employed for structural health monitoring and control systems; current algorithms assume that all data is centrally collected and processed. This approach does not scale to systems with complex and densely instrumented arrays of sensors that will be required for the next generation of structural health monitoring and control systems. This paper provides a brief introduction to smart sensing technology and identifies some of the opportunities and associated challenges."[5].

In paper 'Health Monitoring of Civil Infrastructures Using Wireless Sensor Networks' by Sukun Kim, Shamim Pakzad David E. Culler, published in Center for Information Technology Research in the Interest of Society (CITRIS),it states that " A Wireless Sensor Network (WSN) for Structural Health Monitoring (SHM) is designed, implemented, deployed and tested on the Golden Gate Bridge (GGB). Ambient structural vibrations are reliably measured at a low cost and without interfering with the operation of the bridge. Requirements that SHM impresses on WSN are notified and new options and solutions to meet these requirements are proposed and implemented. In the GGB deployment, 59 nodes are distributed over the span and the tower, collecting ambient vibrations in two directions synchronously at 1KHz rate, with less than 10µs jitter, and with an accuracy of 30µG. The sampled data is gathered particularly over a 44 hop network, with a bandwidth of 461B/s at the 44th hop. The collected data agrees with theoretical models and previous studies of the bridge. The deployment is the largest WSN for SHM."[6]

In paper 'Energy-efficient deployment strategies in structural health monitoring using wireless sensor networks' by Tat S. Fu1, Amitabha Ghosh, Erik A. Johnson and Bhaskar Krishnamachari,published in Struct. Control Health Monit. 2012; 00:1–14,it states that " Structural health monitoring using wireless sensor networks has drawn considerable attention in recent years. The ease of deployment of tiny wireless devices that are coupled with sensors and actuators enhances the data collection process and makes prognostic and preventive maintenance of an infrastructure much easier. In this paper, the deployment problem is focused for identifying node locations to easily diagnose the health of a structure while consuming minimum energy during data collection. A simple shear structure is considered and modal analysis is performed. The example verifies the expectation that placing nodes further apart from each other reduces the mode shape errors but increases the energy consumption during data collection. A minmax, energy-balanced routing tree and optimal grid separation formulation is proposed that minimizes the energy consumption as well as provide fine grain measurements."[7].

In paper 'A Wireless Sensor Network Platform for Structural Health Monitoring: enabling accurate and synchronized measurements through COTS+custom-based design' by R. Severino, R. Gomes, M. Alves, P. Sousa, E. TovarL.F. Ramos, R. Aguilar, P.B. Lourenço,it states that " Structural health monitoring has long been identified as a prominent application of Wireless Sensor Networks (WSNs), as traditional wired-based solutions present some inherent limitations such as installation/maintenance cost, scalability and visual impact. Nevertheless, there is a lack of ready-to-use and off-the-shelf WSN technologies that are able to fulfill some most demanding requirements of these applications, which can span from critical physical infrastructures (e.g. tunnels, bridges, energy grids, mines etc) to old and historical buildings or even industrial machinery and vehicles. Low-power and low-cost yet extremely sensitive and accurate accelerometer and signal acquisition hardware and stringent time synchronization of all sensors data are just examples of the requirements imposed

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by most of these applications. This paper indicates a prototype system for health-monitoring of civil engineering structures that has been jointly conceived by a team of civil, and electrical and computer engineers. It merges the benefits of standard and off-the-shelf (COTS) hardware and communication technologies with a minimum set of custom-designed signal acquisition hardware that is mandatory to fulfill all application requirements."[8].

B. Raspberry Pi:

Raspberry Pi [7] is a small computer board working on the Linux operating system which connects to a computer monitor, keyboard, and mouse. Raspberry Pi can be applied to a electronic structure and programming network work, it can also served as a personal computer and Apache Webserver, MySQL could be installed in the board. A GPIO [10] pin can be used as either a digital input or a digital output, and both operate at 3.3V. Unlike the Arduino, the Raspberry Pi which does not have any analog inputs. For that you must use an external analog-to-digital converter (ADC) or connect the Pi to an interface board must be used.

C. Humidity sensor:

A humidity sensor senses, measures and regularly reports the relative humidity in the air. It measures both moisture and air temperature. Relative humidity, expressed as a percent, is the ratio of actual moisture in the air to the highest amount of moisture air at that temperature can hold. The warmer the air is, it can hold the more moisture, hence the relative humidity changes with fluctuations in temperature.

D. Microelectromechanical systems:

It is the technology of microscopic devices, particularly those with moving parts. It merges at the nano-scale into nano-electromechanical systems (NEMS) and nanotechnology. MEMS are also indicated to as micromachines in Japan, or micro systems technology (MST) in Europe. MEMS are prepared up of components between 1 and 100 micro-metres in size (0.001 to 0.1 mm), and MEMS devices generally range in size from 20 micrometres to a millimetre (i.e. 0.02 to 1.0 mm), although components arranged in arrays (e.g., Digital micromirror devices) can be more than 1000mm^2. They particularly consist of a central unit (CPU) that processes data (the microprocessor) and several components that interact with the surroundings such as microsensors.[1] Because of the large surface area to volume ratio of MEMS, forces produced by ambient electromagnetism (e.g., electrostatic charges and magnetic moments), and fluid dynamics (e.g., surface tension and viscosity) are more important design considerations than with larger scale mechanical devices. MEMS technology is differed from molecular nanotechnology or from the molecular electronics in that the latter must also consider surface chemistry.

The potential of very small machines was appreciated before the technology existed that could make them (see, for example, Richard Feynman's famous 1959 lecture There's Plenty of Room at the Bottom). The MEMS now became practical once as they could be manufactured and fabricated using modified semiconductor device fabrication technologies, normally used to make electronics.[2] These include molding and plating, wet etching (KOH, TMAH) and dry etching (RIE and DRIE), electro discharge machining (EDM), and other technologies capable of manufacturing small devices. The latest example of a MEMS device is the ‘resoning.

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III SYSTEM DEVELOPMENT

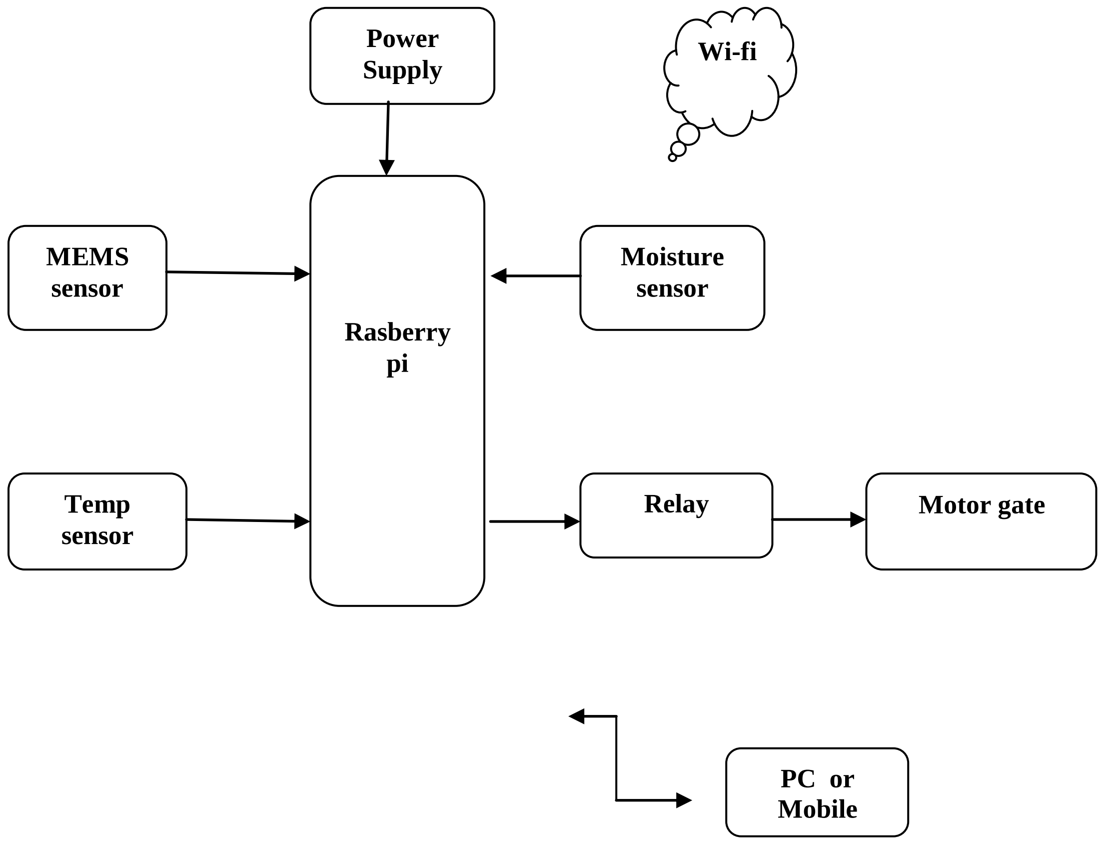

Fig 1: Block Diagram of System

The propose infrastructure health monitoring system is shown in Fig. 1, the sensor integrated with embedded system are mounted on structural members to acquire measurements. In general, the sensor can be any analog or digital transducer of a physical quantity that is useful in determining the state of the infrastructure, such as strain, dynamic acceleration, and displacement. Wi-Fi functionality is integrated to a commercial wireless node to provide the system with the capability of wireless networking. Wireless nodes of the same type in different sections of large-scale infrastructure can operate in a wireless network where the Web server in the same wireless network collects the sensor data which can be accessed via the Internet. This provides the advantage of low-cost, low-power WI-FI technology to support the need of dense population of sensors in large scale infrastructure monitoring and the feasibility of local infrastructure health monitoring using a wireless system. Fig. 1 shows the schematic block diagram of an embedded system section of the measurement system. It includes a sensor integrated with raspberry pi, where an accelerometer is used as the sensor for remotely measuring the dynamic acceleration in civil structures.

Here DHT 11 is used to sense moisture in infrastructure. With Wi-Fi technology the sensors values are updated over webpage. Webpage is capable to show all the runtime sensor values as well as infrastructure health alerts.

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Experimental setup

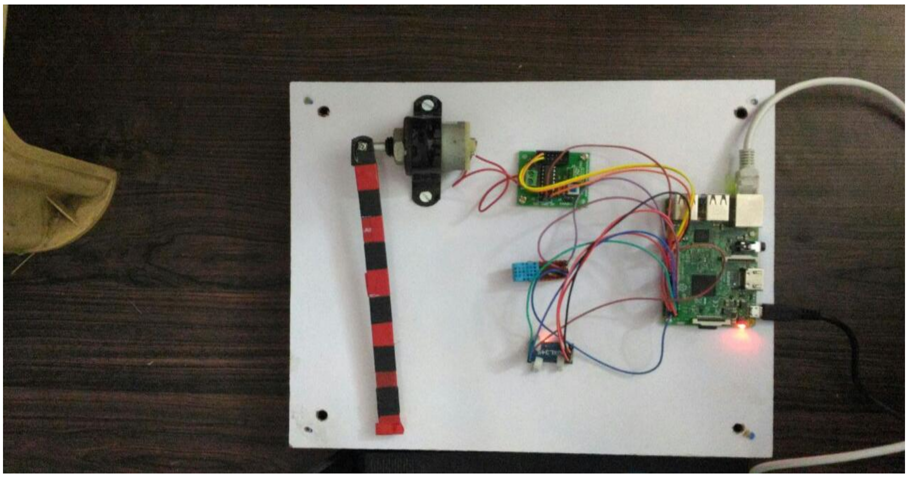

Fig 2 Experimental Set up

IV. RESULT

Log in WebPage:Webpage is only accessed by authorized person by using Email id password,after login Web page the output is get displayed on webpage if threshold value of sensor is get exceeds and gate of bridge is closed

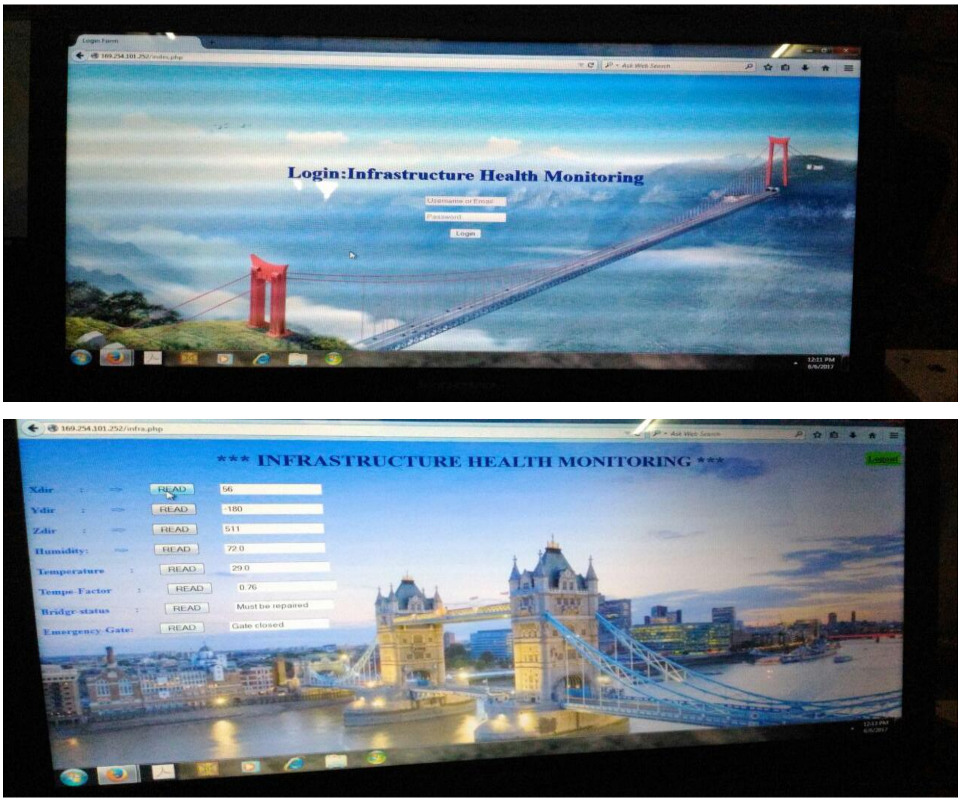

FIG 3: WEBPAGES OF RESULT

V. CONCLUSION

In this paper, a dynamic acceleration measurement system with an accelerometer integrated with embedded system and Wi-Fi was presented for remote monitoring of infrastructure. Design considerations for acquiring maximum possible spectral bandwidth for the prominent axis dynamic acceleration measurements under the limitations of the selected Wi-Fi hardware were discussed. Measurements were conducted using a structural specimen, and the experimental results have shown that the system can acquire natural health information of the structural specimen. The senosors like DHT 11and Mems sensor is working properly with raspberri pi. the raspberri pi has successfully established Wi-Fi network to communicate with the webpage. the webpage is showing continuous evaluation of infrastructural health based on sensor values. The results were validated by practical approach. The experiment with the loaded specimen has shown that the system can distinguish the state changes of structures due to load changes. Therefore, the proposed wireless system can be used for infrastructure health monitoring. As future work, field testing will be done by enhancing the proposed system by incorporating the modified Wi-Fi system which performs better when mounted on structural blocks made out of concrete or metal.

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