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IoT Based Bridge Health Monitoring System

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ABSTRACT: In this project we are analyzing the performance of IoT based bridge health monitoring system to determine the water level, overall weight of the vehicles on the bridge, vibration and deformation. As per the report, as many as 1,217 people died and more than 5,000 people have been injured in incidents of bridge collapses throughout the country in past 15 years. Where in Mumbai around 6 bridges have been collapsed in past 7 years and caused 28 death(2.3 percent) where these are manmade tragedy, where at least one similar incident have been reported in Mumbai since 2010. Where as in Karnataka around 10 bridges have been collapsed in 6 years and it caused death around 5 percent (around 65 death caused). From the review of different journals papers, it is founded that there were no previous studies published in related to the project of the IoT based bridge health monitoring system which uses the private channel for periodic monitoring of the bridge. The key benefit of using IoT (Internet of Things) is that it has a higher degree of output quality, and the introduction of new technology would make the system smarter and more receptive. Using IoT network, we can reduce the risk of human errors and harm to the bridge caused by human and natural disasters can be minimized. The surveillance of bridge is complex task, however employing IoT and cloud would make the system simple as stated further. The tracking sensors serves with important values intended for spotting the impending catastrophe and quickly produce excessive acoustic sound over long distance possible to alert about disaster for people who are using the bridge.

KEY WORDS: IoT, Wi-Fi, Cloud, Private Channel.

I. INTRODUCTION

A bridge is a physical structure built to overcome an obstacles, such as water body, railway track, or a road, without blocking the path under the bridge. Bridge is built for the purpose of crossing over the obstacle. There are many different types of bridge where each of them serves a purpose and it will apply to different scenarios. Designs of bridge varies according to the usage of the bridge, the environment where the bridge is being constructed.

A major revolution in bridge came with the construction of the iron bridge in Shropshire, England in 1778. It used pig iron for first time for the construction of arches to cross the water bodies. Bridge management program consisting of joint monitoring and testing of structural fitness. Testing must be carried out by the engineers who are expert in the field of bridge monitoring in such a way that to monitor the bridge on a regular basis, to inspect the bridge's overall health twice a year, a simple test must be performed every one to four years and a crucial inspection every eight years. It results in a far greater gain, using present bridges that can be used far past the recorded lifespan. Bridges vibrate under heavy load and this adds to the heat, to a greater or lesser degree. Given weaker structures, vibration and dynamics are generally more significant. While the bridge response to the loading applied is well understood, the traffic loading applied to the bridge itself is still being investigated. This is a major problem as loading is highly variable, especially for bridges. Loading effects in bridges (stress, bending moments) are designed for the use of load and resistance factor design principles. There are many different methods used for monitoring the bridge condition. Many long-range bridges are now monitored routinely with a wide range of sensors. Many types of sensors are used, including strain gauges, water level sensors, vibration sensors and flex sensors. Larger bridges are routinely monitored by various electronic sensors and relatively smaller bridges are visually inspected. Research is underway to monitor smaller bridges, as they are often remote and do not have electrical power.

According to the survey conducted by the Union Ministry of Surface Transport (MST) during September-October 2019, 5,500 bridges out of a total of 6,500 bridges are losing their strength to cope with heavy traffic loads. The Ministry is now faced with the problem of nearly 700 bridges in advanced stages of decay. The survey also identified 30 bridges as "highly distressed," 700 in need of major repairs and 2,000 more for routine repairs. In India, the bridge age varies normally between 35 to 45 years. The reason behind the aging of the bridge is the heavy load on the vehicle. The ITO Bridge in Delhi handles more than 15 times the traffic it was designed to withstand. There is therefore a need to monitor the load of the vehicle on the bridge. The cost of building a bridge with a long life is phenomenal. Bridges with shorter lifespans are therefore being built in many parts of our country. Within a certain period of time, another bridge will be constructed to divide the load. But it's never going to happen. This is either a lack of funds or a delay in construction.

II. LITERATURE REVIEW

The proposed system software is divided into several functional blocks to collect, transmit, log, process and asses the bridge status using a fuzzy logic based algorithm. In addition to that, a friendly user graphical interface and Google map based GIS todisplay the real-time and historical status of the monitor bridge. In the process, MATLAB fuzzy logic, database and web service software tools were utilized to develop and test the system.The presented sensor system consists of under-water sensor nodes with the wired Power over Ethernettechnique. The proposed under-water sensor node is implemented with two stacked octagon PCBs and enclosed in a steel hollow ball and then setup in the steel cage. The proposed architecture of the bridge scour monitoring system owns the scalability and flexibility for mass deployment. The presented rugged sensor system is now setup in Ming-Chu Bridge in Taiwan to monitor the bridge scour condition. This section describes the system development which includes selected sensors, implementation tools, system architecture and structural damage detection algorithm. The algorithm is designed based upon the graph theory namely the Weighted Attack Graph (WAG) which is an extension of the decision tree and is widely used in computer network security analysis.

The main points of LW are low power consumption and real-time data collection. For these two targets, we propose a suitable network framework. It consists of four kinds of devices, i.e., Data Collection Device, Base station (Access Point), Router (Range Extender) and End-device. Data Collection Device (DCD) is the control centre of this system. All of the users control programs and collected data samples are run in data collection device. Wireless node module contains Router and Sensor Node (End-device). Sensor node is used for sampling vibration data and realizing real-time transmission. Router is used for extending wireless communication distance of data acquiring system.

This work describes the method of example style and development of a wireless embedded system that uses specific measuring system sensors to get knowledge relevant to health watching of bridges. This paper includes the necessity analysis, style and implementation of a system example exploitation principally free or low-priced technologies. The example conjointly includes an online interface that permits analysis of bridge vibration knowledge among different options.

At present, WBMS is becoming extremely important for high-speed transit routes and for growing conveyance transport network. The analysis work as a whole demonstrates the observation of some essential word of bridge that square measure needed to observe the aging bridges. Remotely built bridges require continuous monitoring and maintenance of safety. The sensing technology and the rapid process talents of the process unit make a man-made effort for structural observation. Computer kit and programming development initiatives build a framework that is economical and free from any external system issues. And the Wireless Bridge Watching Systems (WBMS) will simply determine the health status and predictability of upkeep work.

III. SYSTEM METHODOLOGY

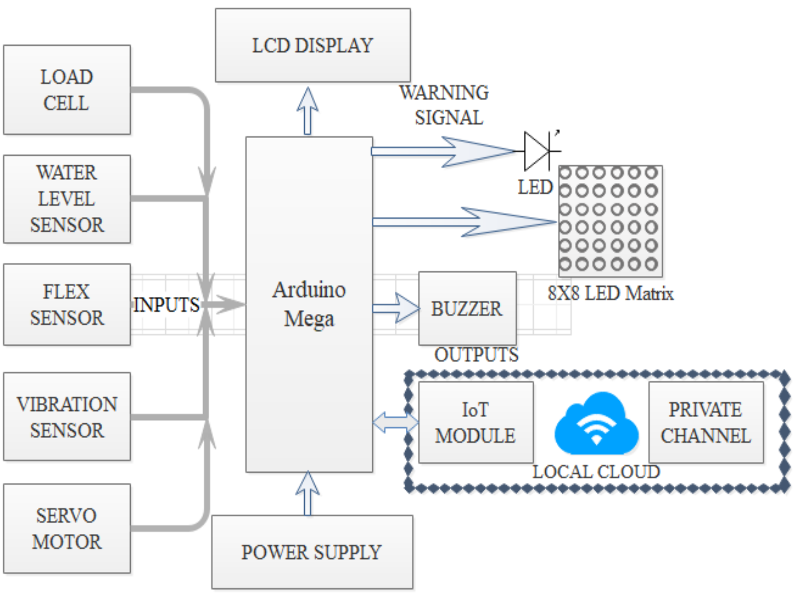

Fig 1.1: Block diagram of the project

Arduino is that the main a part of the system wherever it takes the periodic data from the sensors (i.e. Flex detector, Load cell, Vibration detector and Water level sensor) placed at totally different a part of bridge as shown in figure a pair of.2, if any of the sensors value crosses the threshold value (which is already programmed and hold on into arduino controller) it'll be showed on to the alphanumeric display panel that is gift at room and warning sound are going to be made through the buzzer thereby the alphanumeric display gets updated with this bridge condition within the room. Successively the Wi-Fi module can communicate with the non-public channel or through the native cloud wherever the supervisors will get the notification of the bridge, and that they will access the knowledge from any location.

We are using a magnetic water level sensor it often involves the opening or closing of a mechanical switch, through magnetic operation of a reed. With magnetically actuated float sensors, switching occurs when a permanent magnet sealed inside a float rises or falls to the actuation level. The load cell is of Single point shear beam load cell, they are the kind most often found in industries because it is highly accurate, versatile, and cost-effective it is typically a force transducer that converts a force such as tension, compression, pressure, or torque into an electrical signal that can be measured. As the force applied to the load cell increases, the electrical signal changes proportionally. A conductive ink based flex sensor will be mounted on the bridge beam it measures the amount of deflection or bending. Usually, the sensor is stuck to the surface, and resistance of sensor element is varied by bending the surface. The resistance is directly proportional to the amount of bend. A vibration sensor is a device that uses the principle of piezoelectric effect to measure changes in pressure, acceleration, strain, or force by converting them to an electrical charge. A piezoelectric disk or a crystal will generates a voltage when deformed and vice versa.

Arduino Mega 2560 may be a Microcontroller board supported by Atmega2560. It comes with a lot of memory house and I / O pins compared to different boards available on the market. There are area units of fifty-four digital I / O pins and sixteen analog pins incorporated on the board that make this device distinctive and stand out from the others. Out of fifty-four digital I / O, fifteen area units used for PDM (pulse dimension modulation). ESP8266 can be a low-cost Wi-Fi silicone chip that can be a thirty-two-bit small controller with an eighty megacycle or a hundred and sixty megacycle hardware and an ESP32 successor with an IEEE 802.11 b / g / n Wi-Fi protocol system. Thanks to its wide operating temperature, the ESP8266 is able to operate systematically in industrial environments. With highly integrated on-chip options and stripped off of a separate external element count, the chip offers reliability, compactness and durability. The IoT module can have built-in cloud And a science address wherever any system is connected to the module via a science address and victimization Thing Speak-TM we are able to create a non-public cloud using the victimization API key and the channel ID defined only by the UN Security Agency has the API key that can be linked to the native cloud.

The non-public channel is Victimization Thing Speak™ IoT Analytical Framework that allows you to merge, visualize and analyze live data streams through the cloud that allow you to send data to Think Speak™ from your app, instantly visualize live data, and send notifications through network services. With MATLAB® analytics between Speak issues, you will be able to write and execute MATLAB® code for pre-processing, visualization and analysis. Issue Speak helps engineers and scientists to imagine and construct IoT systems while not repairing servers or designing a network kit. Main objectives of the system is 1.To deploy the various sensors for gathering the parameters of the bridge.2. Estimating the thresholds of different parameters by the signals obtained from the sensors.3. To create a network around the bridge to send periodic information to control room and create a local cloud through IoT module.4. Construction of a bridge prototype for achieving the objectives.

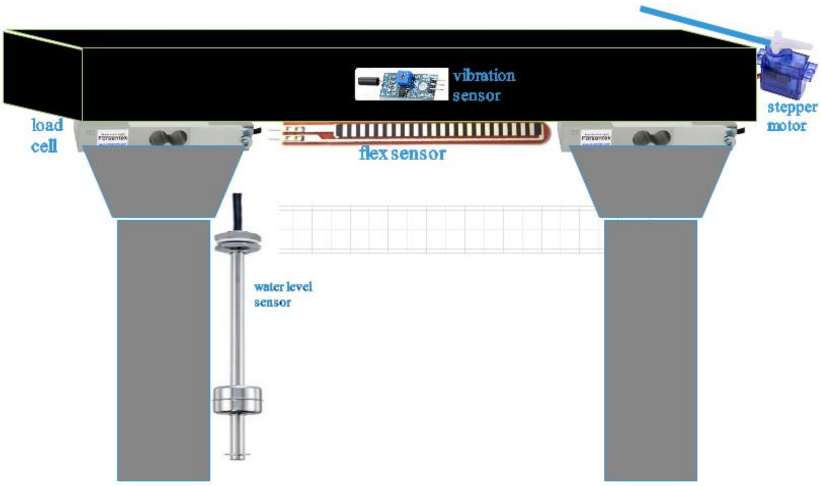

Fig 1.2 Various Sensors Placement in the Bridge

The methodology for achieving the objectives of this project is obtained from the block diagram as shown in the figure 1.2. The sensors (flex, load cell, vibration, and water level) installed on various part of the bridge as shown in the figure where it monitors the deformation, water level, load of the individual vehicle, the overall load on the bridge and amount of vibration periodically. At any point of the time if any of the parameter crosses there threshold value the communication system informs the control room using an alarm and text messages for taking precautionary measures and will be displayed on computer using ThingSpeak™ private channel. Once the threshold value is reached in any of the parameter the entry to bridge will be blocked.The process of restricting the entry and the precautionary measure will be done automatically.

IV. SYSTEM IMPLEMENTATION

The circuit implemented in this work is seen in figure1.3. The hardware components used are mentioned and specified below:

- Arduino MEGA.
- ESP8266 WI-FI module.
- Flex Sensor 2.2".
- Load cell with HX711 amplifier.
- Vibration Sensor SW-18010P.
- PN5 Water level Sensor.
- SG90 9G Servo motor.
- LCD Display 16X2.
- Mini Piezo Buzzer B-10N.

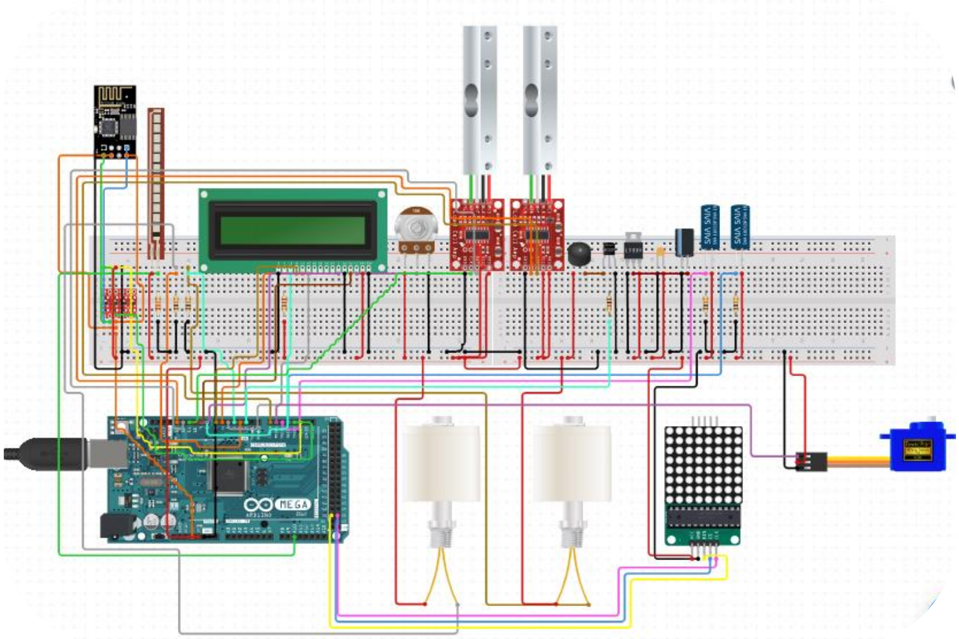

Fig1.3 Circuit diagram of Bridge monitoring system using IoT

Figure 1.3 shows the complete circuit diagram of IoT based bridge health monitoring system, this circuit diagram is developed for the following functions. In this circuit diagram, the pins of varied sensors like the vcc, ground and signal out area unit connected consequently. The signal obtained through this arrangement area unit processed and conjointly needed management action is taken by the microcontroller. The digital display are going to be placed within the room, this displays the signals obtained from the detector sporadically. The same knowledge obtained from the sensors also are updated to the non-public channel through Esp8266 IoT module. This ensures police work of bridge from anyplace. The average weight calculation of the vehicles is completed exploitation 2 load cells, by taking the typical values we are able to confirm the most load that the bridge may carry.

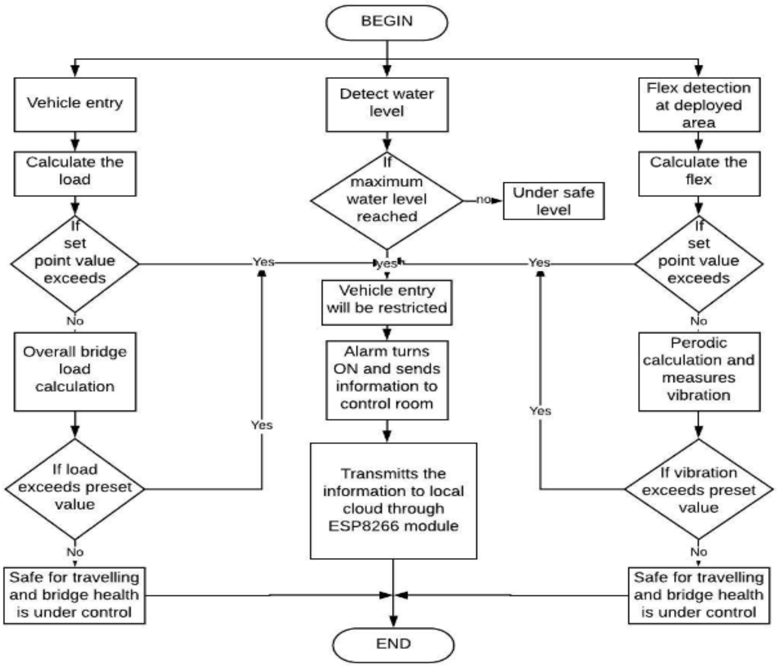

Fig 1.4 Workflow of bridge health monitoring system

At the doorway of the bridge one load cell are going to be placed and also the vehicle load are going to be calculated if the vehicle load crosses the set point value the vehicle entry are going to be restricted, if not then the overall load are going to be calculated if the values are under controlled limit then the bridge is safe for travelling. Simultaneously the water level and flex are going to be calculated, if any of those parameters crosses the set point value the vehicle entry are going to be blocked, when the flex sensor value is under the point then vibration of the bridge is calculated in such a way that value does not cross the preset limit, if the bridge is under good conditions then it's safe for travel. If any problem arises then the vehicle entry are going to be restricted and also the alarm activates and the information is send to the control room where the protection person is suggested to require necessary actions, and also the information is transferred through ESP8266 IoT module to personal channel, and also the officers who has the private key to access the private channel can able to see the bridge condition.

IV. RESULTS AND DISCUSSION

Table shows the output of different sensors place on the bridge. Each sensor value has been tabulated with respect to time duration, for every 2 second time interval the output will be calculated and will be uploaded to local cloud or private channel through IoT module. Threshold value will be set in microcontroller program and if any sensor crosses the threshold value it will be indicated in LCD display and buzzer will be turned ON.

Table1.1 Output Bridge Health Monitoring System

Time Duration (in sec)	Load Cell Value (in gms)	Vibration Sensor Value (in sec)	Float Sensor Value (in ohm)	Flex Sensor Value (in ohms)
0	6631	0	0	0
2	7483	2	741	766
4	8136	9	304	754
6	8550	18	661	768
8	9077	30	405	741
10	9638	3	497	730
12	10294	0	272	722
14	10686	11	610	739
16	11041	71785	688	714
18	11861	4466	308	708
20	12133	20	643	703
22	12640	58235	356	679

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Figure shows the graph of the various sensor values that will be plotted continuously and the numerical data of the current bridge condition will be shown through private channels on the Thing Speak™ website or through the Thing Speak™ mobile application. Hard copy of the graph and the numerical values will be available for future reference in the form of a PDF document.

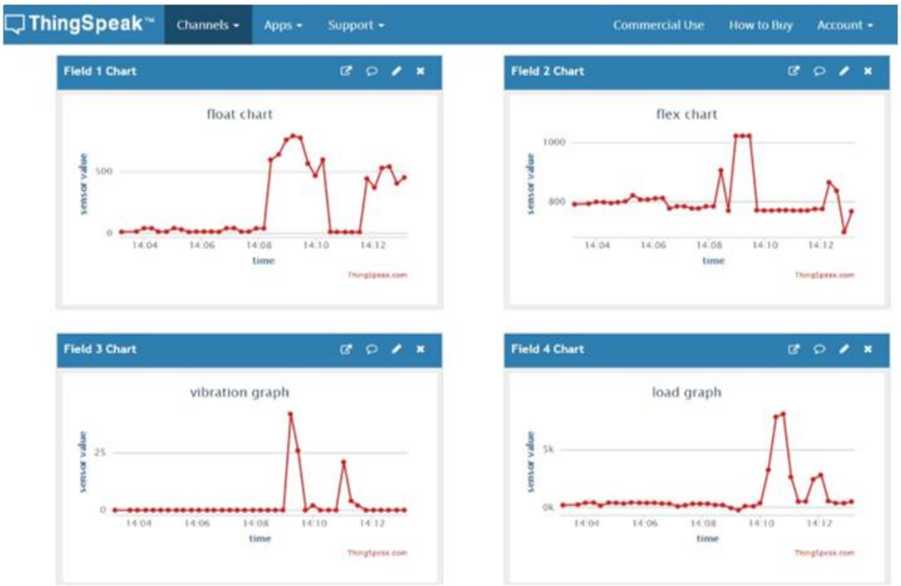

Fig 1.5 Graph of Float, Flex, Vibration and Load Sensor

V. CONCLUSION AND FUTURE SCOPE

The project mainly focus upon developing an IoT Based Bridge Health Monitoring System. The system was designed with the help of various type of sensors(Float, Vibration, Flex and load cell) and Arduino mega micro-controller and IoT module. There are many objectives focusing towards development of Software and Hardware, firstly deploying various sensors on the bridge for gathering different parameters of the bridge as mentioned in the chapter 2. Second objective is estimation of threshold of different parameters by the signal obtained from the sensor, to create a network around the bridge to send the periodic information to the control room and finally creating a local cloud with the help of IoT module and uploading the information of the bridge to cloud. By constructing the prototype of the bridge for achieving the above listed objectives. The sensors has been successfully deployed and tested with different threshold values and set points. The sensors were tested on the bridge surface and gave expected result as discussed in the results section. The IoT Based Bridge Health Monitoring System was implemented by using IoT module with the help of libraries and coding environment based on the C programming. Bridge algorithm was successful in detecting the values by outlining the object of interest and identifying the vibration, water level, deformation and load of the vehicle on bridge.

For future work we can implement the following objectives:

1. As of now we are only focusing on the deformation monitoring of the bridge using flex sensor, by using high quality digital flex sensor we can calculate the crack at exact location in the bridge.
2. Laser technique can be used i.e. passing a laser beam at one point of bridge and receiving at another point, by implementing this technique we can detect the crack without the image processing technique.
3. By using image processing technique we can find the crack at exact location by using aerial camera or drone cameras, because the camera one which is fixed on the bridge can't capture the image of crack as the bridge tend to vibrate as the vehicle travels.
4. By installing high frequency 3D sonar around the pillar of the bridge which has submerged underwater to find the aging of a bridge's pillar.

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