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A Review on IoT Based Bridge Monitoring Systems

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***Abstract*: Every year, new bridges are constructed, and oftentimes, the upkeep of such bridges is neglected. It's critical to monitor the bridge because a malfunctioning one could result in numerous accidents. To prevent any failures, a system is therefore required to keep an eye on the bridge's strength or stability. With wireless technology, a bridge safety monitoring system is built, based on the Internet of Things. This system consists of bridge monitoring devices located in the environment, together with the communication devices that link the cloud-based server and the bridge monitoring devices. The water level sensor, load sensor, TDS sensor, RF transmitter, servo motor, and ultrasonic sensor are just a few of the sensors that this system can monitor and evaluate in relation to a bridge and its surroundings. With the aid of mobile communications devices, users can monitor bridge conditions in real-time by sending the discovered data to the server and database. This system measures the weight of the cars; if the value exceeds a threshold, it sounds an alert and shows the message on an LCD. The responsible authority can then designate the workers to do the maintenance.**

***Keywords*: Arduino Uno, Cloud server, IoT, Load sensor, TDS sensor, RF transmitter, Servo motor.**

1. Introduction

The deteriorating effects of aging materials, extensive corrosion of the steel reinforcing bars in concrete structures, rising traffic volumes, and overloading are all constant threats to bridges. These are in addition to construction and design flaws and unintentional damage. Even though their lifespans are coming to an end, many of the bridges in cities situated along rivers are still in operation despite their deterioration. Users of the bridge are at risk from them. These bridges may collapse from large car loads, high water levels or pressure, or severe storms, which would be disastrous. The Bridge Monitoring System (BMS) gives us advance notice of situations in which we can prevent loss and potentially save a great number of lives. BMS is a tool for enhancing bridge maintainability and safety. Accurate and up-to-date information regarding the structural health state is provided by BMS.

The technology created in this study has the potential to lower accident rates and improve bridge safety monitoring against many disasters, including wind, earthquakes, floods, heavy loads, and vibrations. We suggest utilizing IOT to create an integrated bridge monitoring system that can stop mishaps or structural collapses. Every sensor obtains the current value and transmits it to the server. The system will sound the buzzer and alert the public if the sensor value exceeds the limit.

The Bridge Monitoring System's goals are to:

- Constantly monitor the bridges; sense the surroundings and transmit data to a web application via the server; and generate an alert via an auto-barrier and buzzer in the event that the level of water in a river or the load of vehicles exceeds a threshold.
- The objective of the project is to create a cloud-based server that computes and analyzes data received from the monitoring devices, a dynamic database that stores information about the condition of the bridge, communication devices that link the bridge monitoring devices and the cloud-based server, and monitoring devices installed in the bridge environment.
- Real-time monitoring and analysis of a bridge's surroundings, such as water levels and other safety factors, will be done by this system.

2. Literature Review

A structural health monitoring system for bridges was proposed by Tirth Patel, Abhishek Jain, Dharak Gameti, Umang Patel, and Rutu Parekh in [1]. Bridge vibration is measured by means of the accelerometer within the system. The Arduino UNO's Bluetooth module picks up the vibration's frequency and sends it to a receiver. The receiver performs the required MATLAB computations in order to locate the damage and determine its severity. It is possible to use the damage to determine when and where the bridge needs to be rebuilt.

In Pradeep Kumara V.H. and D.C. Shubhangi proposed design is useful for flyovers and bridge monitoring [2]. Monitoring devices in the form of sensors, such as tilt, vibration, load, and water level sensors, are integrated into the design. A database is employed to keep track of a bridge's state. The monitoring devices receive data, which is calculated and analyzed using the CPU. Bridges and flyovers are being monitored in real-time by the design.

In Lingzhi Yi et al. (2020), in [3], the academic and industry communities of computer science and civil engineering have recently given the Internet of Things (IoT) based Bridge

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Structural Health Monitoring (BSHM) a great deal of attention. This study investigated a basic issue driven from real-world IoT-based BSHM in collaboration with researchers in computer science and civil engineering: how to efficiently extend network lifetime while ensuring required coverage. In order to ensure network coverage and extend network lifetime, this paper presented an energy-efficient sensor scheduling strategy for partial CIC coverage in an Internet of Things-based base station health monitoring (BSHM) system. This strategy integrated a promising reinforcement learning model called Learning Automata with Confident Information Coverage (CIC) model. The suggested plan alternately schedules the wake/sleep status of nodes and fully utilizes cooperation among deployed nodes.

In Arohi D. Sonawane, Pooja P. Vichare, Shubham. S. Patil and Nitin. P. Chavande proposed IoT-based bridge monitoring system approach attempts to make the process of choosing bridge tracking devices simpler [4]. In order to securely extend the life of the numerous outdated or structurally flawed bridges found in India, an inspection is essential. It is quite unrealistic to expect a bridge engineer to be knowledgeable about all of their responsibilities. When our technology detects a breach in the bridge, a signal to govern rooms may be sent. The Atmega is interfaced with the sensors and LCD. Flex sensors are employed. The value is set to detect any tilt or small cracks; if the tilt or crack exceeds our predetermined value, a crack is identified.

A. R. Pawar the purpose of the structural health monitoring system is to continuously and real-time measure the critical parameters of the environmental and structural states [5]. The detection of structural problems, safety, catastrophe mitigation, etc. are the goals of SHM. Wireless sensors to track environmental or physical parameters, such as water level, acceleration, and pressure. Wireless sensors are used to measure water level, pillar tilt, and acceleration in bridge and dam applications. Industry, urban terrain tracking, civil structure monitoring, security and surveillance, smart buildings, and other applications use wireless sensor networks.

Pooja Krishnath Patil four parts make up the proposed system [6]: a cloud-based server that computes and analyzes data received from the monitoring devices; monitoring devices installed in the bridge environment; and communication devices connecting the bridge monitoring devices and the cloud-based server. The dynamic database contains information about the state of the bridge. This technology allows for real-time monitoring and analysis of the environment around a bridge, including nearby water levels, pipelines, air quality, and other safety considerations. By transmitting the detected information and photos to the server and database, users can use mobile devices to monitor the bridge conditions in real time.

Rishikesh N, Sriramu D, Surendran R, and Varshini V R suggested IoT-based bridge monitoring and alert generation system [7].This study suggests a system that includes an ARM microcontroller, water, force, weight, vibration, and Wi-Fi modules. When the weight of vehicles exceeds a certain level, this system detects it and sounds an alarm. The responsible authority can then assign the work to the personnel for maintenance.

Amrita Argade, Sanika Chiplunkar, Rohini Kumbhar, Varsha Kusal, and Prof. Swati A. Khodke [8] suggest a system that includes an Arduino microcontroller, a weight sensor, a WiFi module, and a water level point contact sensor. This system measures pressure, water level, and vehicle load. The buzzer and auto barrier will sound an alert if the water level, water pressure, and vehicle load on the bridge exceed their threshold values.

The project, as proposed by Prajwal, Goutham, Kiran, Shiva Prasad, D R, and Dr. K V Padmaja [9], focuses primarily on creating an Internet of Things-based bridge health monitoring system. Float, vibration, flex, and load cell sensors, as well as an Arduino mega microcontroller and an Internet of Things module, were used in the system's design. There are numerous goals centered on the development of hardware and software. The first goal is the installation of different sensors on the bridge to collect various bridge parameters. The determination of threshold for various parameters using the signal derived from the sensor is the second goal to build a network surrounding the bridge in order to transmit data to the control center on a regular basis. Lastly, to use an IoT module to build a local cloud and upload data from the bridge to it. by building the bridge prototype in order to accomplish the aforementioned goals. The sensors have been successfully installed and tested with various set points and threshold values. As stated in the findings section, the sensors' expected results from testing on the bridge's surface were obtained. Using libraries and a C-based coding environment, an IoT module was used to create the IoT-based bridge health monitoring system. By defining the item of interest and specifying the values, the Bridge method was able to successfully find the water level, vibration, load and deformation of the vehicle on bridge.

The four sensors utilized in the block diagram—the temperature sensor, the accelerometer, the strain gauge, and the anemometer—were proposed by Atharva Kekare, Pranit Huddedar, and Rohit Bagde [10]. The bridge tilt is detected by the accelerometer. It detects the bridge's motion in three dimensions. The accelerometer will be connected at the center of the bridge. The temperature of the bridge's components can then be determined by the temperature sensor. Any portion of the bridge may be connected to the temperature sensor. The weight that the bridge is holding at any one moment can be determined using a strain gauge. For this, a load cell has been utilized. At the middle of the bridge is where the load cell is connected. Anemometers are sensors that gauge speed.

Sharmikha Sree R, Meera S, Deepika R, Divya S and Priyadarshini V [11] proposed IoT-based automated bridge monitoring system. It locates the crack in the bridge that results from accidents or overload. It is important for keeping an eye on flyovers and bridges since it can automatically identify cracks, checks, and increases in vibration. Additionally, it keeps an eye on the bridge's lighting, particularly at night, and determines whether the heat generated by the cables could start a fire. It also looks for fires.

Divya Muddala, Dhanashree Kamble, Pooja Nimbalkar, Ravina Patil and Sathish K. Penchala [12] they suggested and created a more secure bridge monitoring architecture that include the different factors affecting a bridge's structural integrity. The monitoring system, which consists of a central server, an intelligent acquisition node, and a local controller, uses a three-level distributed structure. This system can identify deviations from the line of sight, water level, and the presence of multiple vehicles (high amplitude vibrations). The buzzer and auto barrier will sound an alert if any of the following conditions are not met: the water level, water pressure, vehicle load on the bridge, and line of sight. Both the water level and the condition of the bridge have been inspected. They have included the ability to broadcast the message to users, the municipal office, the rescue team and the police station in an emergency situations.

Farida Iasha and Purwadi Agus Darwito [13], they suggested using an algorithmic approach to assess the bridge's capabilities to ensure that the arriving vehicle's weight does not exceed the bridge limit. The control algorithm applied on the bridge is when the vehicle enters the bridge, the load cell sensor will detect the weight of the vehicle and the accelerometer sensor detects the vehicle's position. If the vehicle load exceeds the maximum bridge load capacity specified, then the portal will close the bridge and vice versa. Information about the condition of the bridge is displayed via the Internet of Things (IoT) based website. The load cell sensor on the bridge will detect the vehicle's weight while it enters, and the accelerometer sensor will determine the vehicle's position. This is the control algorithm that is used on the bridge.

Jin-Lian Lee0, Yaw-Yauan Tyan, Ming-Hui Wen, Yun-Wu Wu [14], this paper presents a study on the development of an IoT-based bridge safety monitoring system using ZigBee technology. The system can monitor and analyze in real time the conditions of a bridge and its environment, including water levels, pipelines, air, and other safety conditions. The system uses solar power as a supplementary power source to reduce costs and conserve energy. The collected environmental data can be used for big data analysis or follow-up research. The system is intended to enable 24x7 bridge safety management and appropriate responses to emergency incidents. Future research is needed to improve the system by analyzing data collected by the system and developing more advanced computing models and operational practices for the system.

Y. B. Yang, Hao Xu, Bin Zhang, Feng Xiong, Z.L. Wang [15] This paper presents the bridge frequency measurements made by a test vehicle in both moving and stationary conditions are reported in this paper. It was discovered that the vehicle can detect more bridge frequencies when it is stationary than when it is moving. The test vehicle's transmissibility in the stationary state is good, according to the study's conclusions, which were reached using the current tools and the bridge under test. In addition, with the theoretical conclusion of the literature, it is confirmed that the contact-point response computed by the backward substitution process is independent of the vehicle frequency. The bridge frequencies found from the contact-point response seem to be more exceptional than those found from the car-body response for the test vehicle when it is moving. When the test vehicle is stationary, more bridge frequencies can be recorded than when it is moving. The bridge's first two frequencies can be obtained from the test vehicle in both moving and stationary conditions by using the current tools and process.

B. Dhanalakshmi, A. Prakadeesh, and R Roshan Kumarn [16] proposed that by using IoT, the Bridge Safety Monitoring System need to prevent flyover and bridge structural disasters and accidents. In order to prevent traffic near the bridges during flood conditions, an ultrasonic sensor has been used to detect the water level. Additionally, a vibration sensor has been used to assess the bridge's condition. If there is an issue, the bridge is closed by the servo motor. Through the message broadcasting feature, the alert will be sent to the relevant parties so they can take the appropriate maintenance action. This project's primary goal is to prevent numerous tragedies and deaths close to the bridge.

Debajyoti Misra, Gautam Das, Debaprasad Das [17], they have suggested that utilizing an intelligent electronic cyber-physical structure to monitor the health of buildings. The model is built around an Internet of Things sensing Bridge Health Monitoring (BHM) that can identify damage and sends the data to a cloud server for processing and storage via the internet. Microcontrollers, timing devices, WiFi modules, and cloud servers Thingspeak have all been utilized by them. A microcontroller is used to run a mathematical model in order to determine the structural health. The microcontroller uses other electronic parts such as PZT, sensors, etc., to determine whether the structure has any damage. The building's cracks are detected by the system, and possible trouble spots are noted.

Pranav Uttarwar, Akash Khichi, Komal Kand, Abhijeet Tilekar, S. L. Kothawale [18] An Internet of Things (IoT)-based Bridge Health Monitoring System uses a variety of sensors, including weight, water level, temperature, wind speed and cracks, to provide real-time monitoring of the state of the bridge. After that, the data is wirelessly transferred to the management center, where Arduino analyzes that. The operator's mobile number receives an alert message if the sensor readings crosses the critical values. To gather and send data, it makes use of a number of parts, including an Ardunio UNO, a vibration detector, and a sound buzzer. A microcontroller board called the Arduino UNO is used to operate the sensors and gather data. Any movements or vibrations in the bridge's structure are found using the vibration detector. If the sensor readings change, an audible alert is produced by the sound buzzer. The system is designed in such way that it is easy to use and operate. The user can access the data from the sensors that is displayed on the LCD. In order to obtain a comprehensive understanding of the bridge's conditions, the user can also access the data that is kept in the database. The system provides real-time monitoring data of bridge conditions, which lowers costs and helps prevent accidents.

Gaurav Agrawal, Yogesh Jadhav, Sreeranjini Nair, Anurag Kumar and Prof. Sinu Nambiar [19] proposed that in order to prevent accidents and tragedies on bridges, an Internet of things (IOT)-based bridge safety monitoring system uses wireless sensor nodes to gather data on the weather, sound, air quality, and high-priority structures. It consists of an android application and a web application for data transmission and analysis regarding the state of the bridge structure to the public. This system uses a variety of sensors, including temperature, vibration, load cell, and ultrasonic sensors, to continuously monitor the state of the bridge. The load cell sensors identify the weight bearing capacity of the bridge, the vibration sensor the bridge's vibration, and the ultrasonic sensor the water level. Every sensor provides real-time data that is sent to the Android and server. The data that was sent by the system can be examined by the analyst by logging into the Android device. The LCD is going to show the data. The system will alert users with a buzzer if the sensor value exceeds the particular limit.

Sheetal A. Singh and Suresh S. Balpande [20], the main goal of this research is to develop a scalable system that uses multimodal inputs, controllers, and Wi-Fi modules to monitor the loading and vibration of bridges. After being mounted on the prototype, the accelerometer and load cells were tested for a sample load with induced vibration. The data was processed, shown on the device, and uploaded to the Thing Speak cloud service. This system will make it easier for the maintenance staff to keep an eye on it regularly. If the threshold value for any of these parameters is exceeded, the system has the ability to send out notifications. By creating a sophisticated system with industry-grade sensors and controllers and adapting it for practical use, this work can be expanded.

3. Bridge Monitoring System

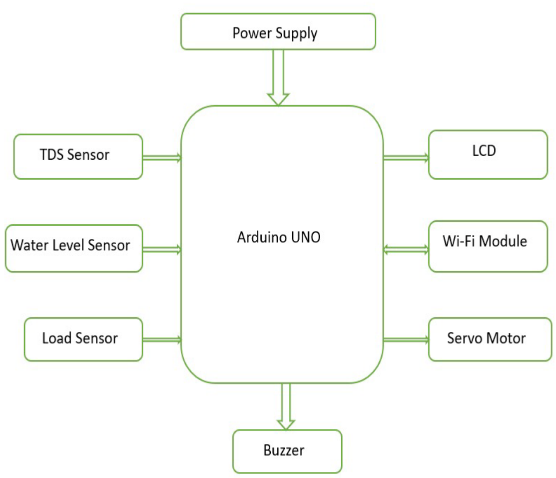

Fig. 1. General operating block diagram of bridge monitoring system

A variety of sensors, including an ultrasonic sensor, a servo motor, an RF transmitter, a load sensor, a TDS sensor, and a water level sensor make up the Bridge Monitoring System. The water level sensor will be positioned between the gaps and beneath the bridge. The Arduino UNO will become alerted when water contacts the sensor. The weight or load on the bridge is detected using load sensors. The salinity of the water is measured using TDS sensors because high salinity causes the iron rods used to build bridges to corrode, which in turn causes the bridge to deteriorate. If a problem or danger is found close to the bridge, an RF transmitter is utilized to take a detour before 2 km. An LCD is retained so that it will show the word "DANGER" if there is any risk or if the system detects a problem. Moreover, servo motors are used to close the highways, preventing any cars from approaching the bridge. It is situated in front of the bridge. When danger is recognized, a buzzer is also utilized to raise awareness. The data is sent to the server via the wi-fi modem. In order to avoid accidents during vehicle passing, ultrasonic sensors are employed to maintain the space between vehicles.

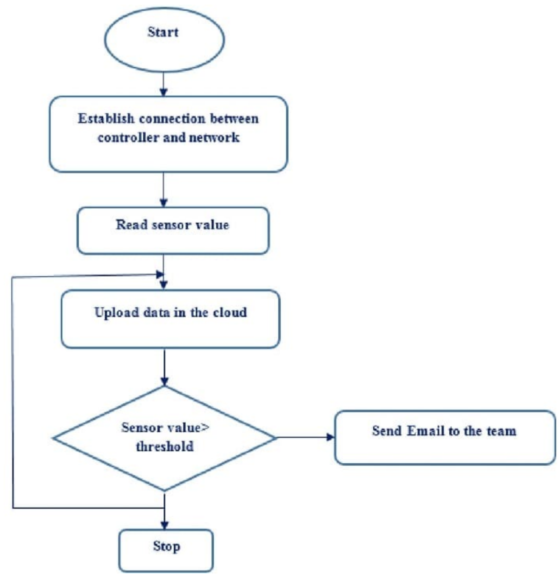

Fig. 2. Flow chart of bridge monitoring system

4. Conclusion

In this study, we describe the operation of an IOT-based bridge monitoring and alert generation system that allows us to display data on an LCD display and an IOT when the bridge shows signs of collapsing. Future catastrophic events will be less frequent because to this system. Numerous lives can be saved by this approach. The solution for bridge damage detection is provided by the IoT combined with the sensors. The suggested system has the ability to provide information regarding the bridge's angle change. For public safety, a bridge monitoring system is required. TCP/IP protocol can be used to construct such a system, allowing the sensor and Arduino or WiFi module to be connected. Finding bridge damage through the deployment of a sensor network is the main goal. A method to tackle damage in bridge health monitoring is through a combination of sensors and the internet of things.

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