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Tiny Sensor Node for Structural Health Monitoring

Pooja Madhav Suryawanshi[1], Laxmikant K Shevada[2]
[1]ME Student, [2]Assistant Professor, DIEMS Aurangabad, Deogiri Institute of Engineering and Management Studies Aurangabad, Dr. BAMU Aurangabad

Abstract: The use of tiny sensor system in structural health monitoring is growing now days, because of the increasing demand for both safety and security. So much work has done and development is going on for sensing internal physical conditions of civil structure. The cities are developing very fast and space utilization is optimum. Ones the civil structure building is complete most likely people needs immediate another structure next to it. If in case some modification in structure is required just like, to increase the floor, change of live load etc. then we need to have real time data. As stated earlier structures are very close to each other space requires for rebuilding is limited and reconstruction cost is also high. It's better to inspect structural health so that further action can be taken. In this paper we trying explore the benefits of structural health monitoring system using tiny sensor node. This node has IoT connectivity to upload data on internet for analysis.
Keywords: Structural health monitoring, IoT based SHM, Wireless power transfer, WSN, Battery free Nodes

I. INTRODUCTION

Civil structures generally required very high investment of not only land but material required also. That's why it should long last as it is expected. But its fitness depends upon various parameters like shape, uses, environmental condition, variations in material used, structure age. By monitoring these structure helps in preventive maintenance. We can analyse exactly where and what type service required. The important benefit of structural health monitoring is that reduces risk of collapse. Sensor nodes are encapsulated in civil structure to sense physical conditions of respective area. These sensor nodes communicate with master node. All sensors data gathered in master node which sends the data to cloud for analysis.

II. LITERATURE SURVEY

We have studied paper related to SHM with some benefits and drawbacks as follows.

A. SHM using Battery Free Sensor Node

The first paper by ALEXANDRU TAKACS[1] implemented SHM using battery free sensing node. It was excellent idea to have sensing node completely wireless even don't require power connections. This type of node can be used SHM without fear as there is no power cable in the structure which can damage by structure or short circuit in cable can cause fire another problem. As Shown in fig.1 Sensing node consist of MCU, PMU, Supercapcitor and LoRaWAN. Sensors used are temperature and humidity. In power management unit rectenna and supercapacitor are the main part for overall power requirement.

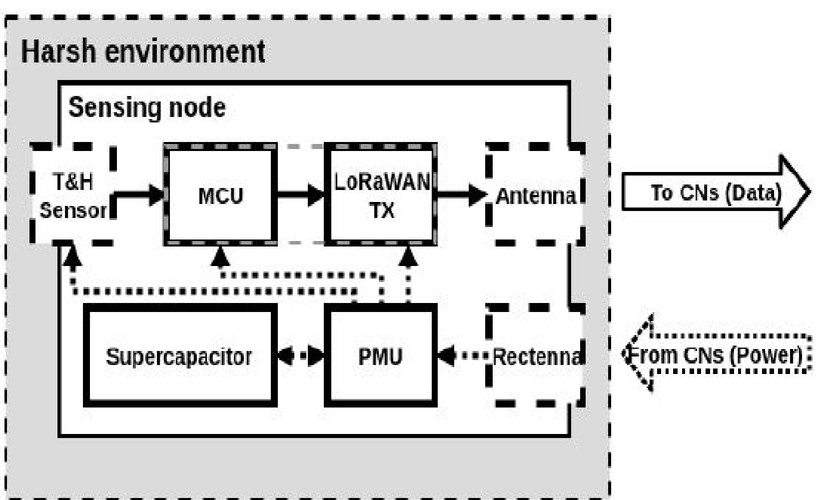

Fig. 1 Sensing node

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The principle used here is conversion of RF power into DC out. a specially designed rectenna was tuned to operate around the ISM 868MHzfrequency band. A compact broadband dipole antenna (enclosed by a rectangular ring, manufactured on FR4 substrate -thickness: 0.8 mm, relative electric permittivity: 4.4 and loss tangent: 0.02-) which captures the low ambient -and generated-electromagnetic energy field and converts it into a RF signal, a single Schottky diode (Avago HSMS 2850 mounted in series configuration) high-frequency rectifier (manufactured on Rogers RT/Duroid 5870 substrate -thickness: 0.787 mm, relative electric permittivity:2.3 and loss tangent: 0.0012- and connected with the antenna in parallel plan to have a 2-dimensional rectenna) which converts the guided RF signal into the dc power. To improve the rectenna efficiency, they used a reflector positioned at 5 cm behind it and measuring 9 cm x 15 cm. In this way, the directivity and the gain of the antenna are increased in the opposite direction with the respect of the added reflector.

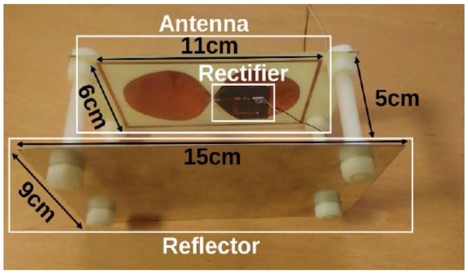

Fig. 2 Photograph of rectenna

1) *Advantages*
a) Does not require external wire connection to power up sensing node.
b) Long range can be obtained by LoRaWAN which operate on 868 MHz ISM

2) *Limitations*
a) Rectenna size is very large to sandwich it into wall or concrete structure.
b) LoRaWAN used here is unidirectional
c) Once The RF power fed supercapacitor needs to be charge up to threshold value then only node operate
d) Node will send only temperature and humidity of structure.

B. SHM using wireless sensor network.

Billie F. SPENCER [2] This paper provided a brief introduction to smart sensing technology, identifying a number of the opportunities, as well as some of the associated challenges. Smart sensors based on the Mote2 paradigm will provide the impetus for development of the next generation of structural health monitoring systems.

1) *Limitation:* The challenges using Mote2 is that it is battery operated needs provision to replace battery hence cannot place it inside solid structure.

C. SHM with WiFi interface and acceleration sensor

H. Chang[3] has published paper in which the IoT sensor device that approach contains a microcontroller chip, ESP8266, and an ADXL345 accelerometer. ESP8266 is a commercial IoT microcontroller that provides wireless capability and small size flash memory. ESP8266 also has station infrastructure (STA) mode that sets a service set identifier (SSID) to allow end user computers to connect to its wireless network. When a user's browser links to the SSID's network and obtains a local IP address during STA mode, a web user interface for configuring the device is shown for users. Inside this configuration page, there is a unique identification number. Therefore, the HTTP server can use this number to identify the device, associate with its location, and then do computation for 3D model visualization.

1) *Advantages*
a) This model use ADXL345 accelerometer by using this real time vibration and displacement in structure can be estimated.
b) Wireless connectivity as well as Internet connectivity obtained by ESP8266 so that data analysis can be done on server.
2) *Limitations*

a) This model also needs external power supply or battery hence too much wiring in structure
b) Only accelerometer sensor is used cannot monitor temperature, Humidity, Load.

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D. *Survey paper on SHM*

C. Jr. Arcadius Tokognon [4] has published the survey paper in which he highlight various aspects that are to be consider while designing SHM. Some of the important aspects are as follow

1) Low-power consumption, which provides a long life of sensing devices battery and increase network lifetime from 5 to 10+ years.
2) The selection of reliability and safety sensors.
3) Most of the solutions use licensed or unlicensed spectrum bands (cellular or noncellular technologies).
4) Short or long geographical coverage (ZigBee/IEEE 802.15.4 standards, low-power Wi-Fi, or LPWAN technologies).

E. *SHM using IoT with vibration and displacement monitoring*

Anirudh Sanjay Patil[5] has implemented SHM using ADXL345 ,piezoelectric sensor and moisture sensor. Following are the features of it.

1) Proposed system will avoid death of people due to bridge collapse.
2) We can determine which bridge requires repairing before it gets break.
3) Traffic can be routed prior of Bridge collapse as alert of extreme levels are continuously monitored on IOT server.
4) It generates the alert if flow, water level, and the load are increased.
5) Early damage detection, Quick action and responses.

a) *Limitations*

Following are some of the limitations of the project:

- Constant maintenance of the system
- Replacement of sensors
- Sudden power cutoffs

III.PROPOSED SYSTEM

From the literature survey we came across some advantages and limitations of existing implemented systems.
Hence we tried to overcome the limitations proposed SHM as fallows by incorporating following features.

1) Sensor node must have wireless connectivity for data transfer.
2) Node must be small in size to encapsulate into civil structure.
3) Monitoring of almost all parameter Temperature, Humidity, Load, and Displacement.
4) Sensor node with bidirectional transreceiver with low power consumption.

A. *System Design*

To fulfil the objectives of Structural health monitoring system we selected the system components as in block diagram. We compared various wireless technologies as shown in table. Our requirement is that transceiver should communicate directly with server. Hence we selected ESP8266 because of its inbuilt wifi connectivity. The Esp8266 has been power up by battery management unit which consume power from super capacitor. Node can operate for about two days once the super capacitor is charged. For measurement of displacement, vibration, acceleration ADXL345 sensor is used. The temperature and humidity measurement DHT22 sensor connected to ESP8266.

Table1 Caparison Of transceiver for Sensor Node

Parameter	LoRaWAN	nRF24L01	Esp8266
power	12.5dBm	-20~10 dBm	Output power of PA for 72.2 Mbps 16.5 dBm
Modulation	lora	FSK	BPSK
Sensitivity	-132dBm@LoRa	-115dBm @FSK	–93dBm @ 6 Mbps (1/2 BPSK)
Receiving current	10mA	7mA	56 mA
Emission current	60mA	36mA	140- mA

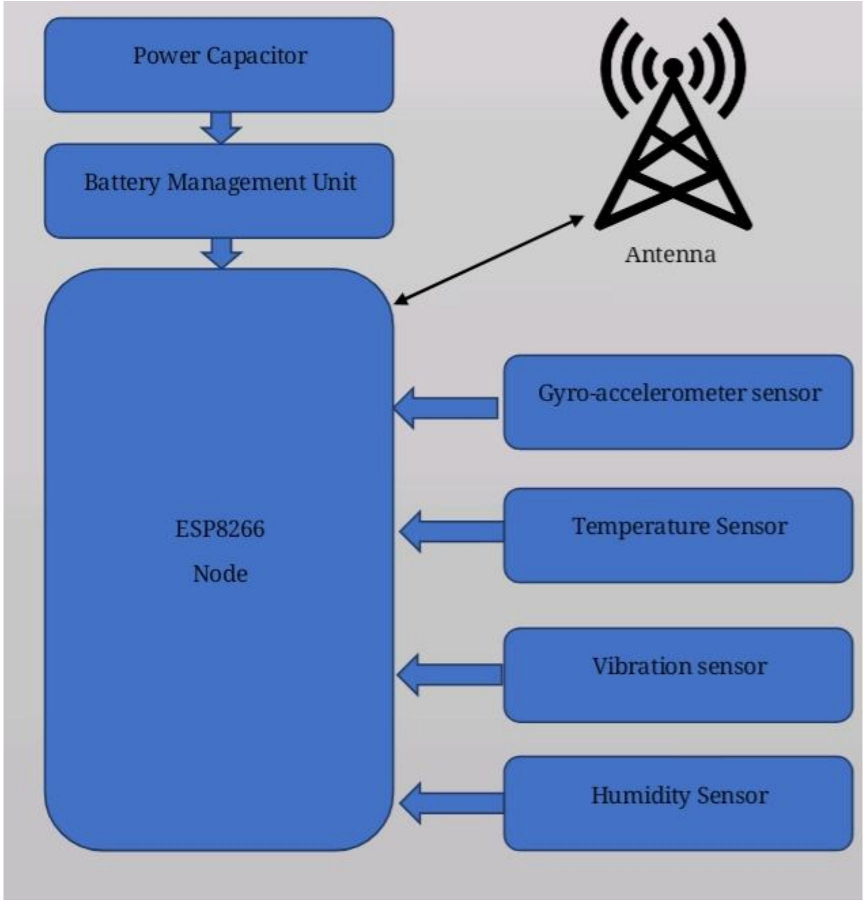

Fig. 3 Sensor Node block diagram

IV. RESULT

We have place Sensor Node inside concrete structure to obtained results. The parameters which we are monitoring visualize on server by accessing node IP address as shown in photograph. For obtaining results we have to just power up the node and access the data. We can have several nodes at different position with different IP addresses by which overall structural health condition can be estimated.

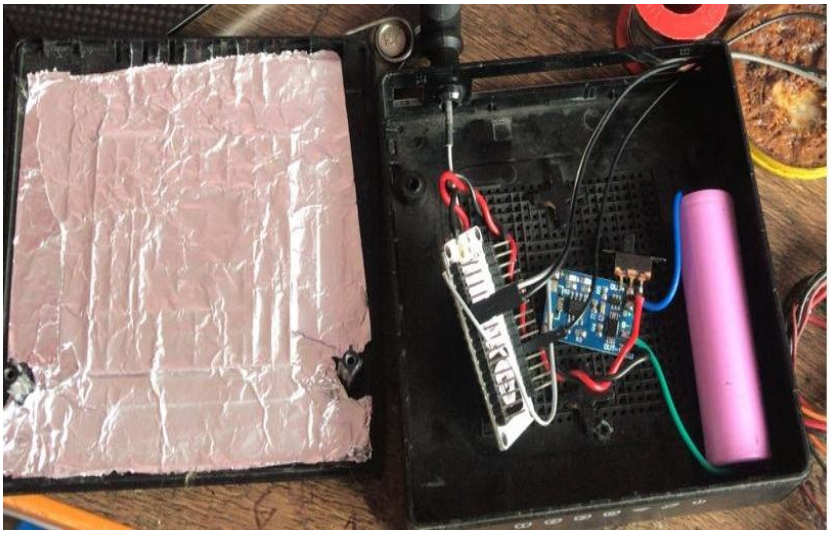

Fig. 4 Photograph of Sensor Node

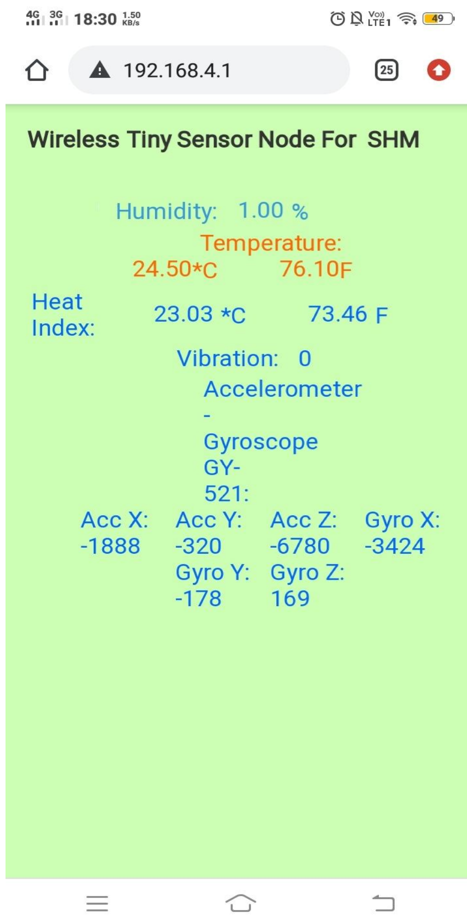

Fig. 5 Result obtained in web browser

V. CONCLUSION

From result it is clear that sensor node works fine within civil concrete structure. Sensor attached to it works and send physical condition sense data to Server. The battery management unit supply power to inside sensor node but only limitation is of it needs to recharge after 2 days. The RF signal successfully passes through concrete structure. We developed Tiny size of sensor node which can be easily sandwich in concrete structure without disturbing the civil design. Although it consume some space but it is negligible. The future modification that can be done in system is, provide wireless power transfer and keep the node size small.

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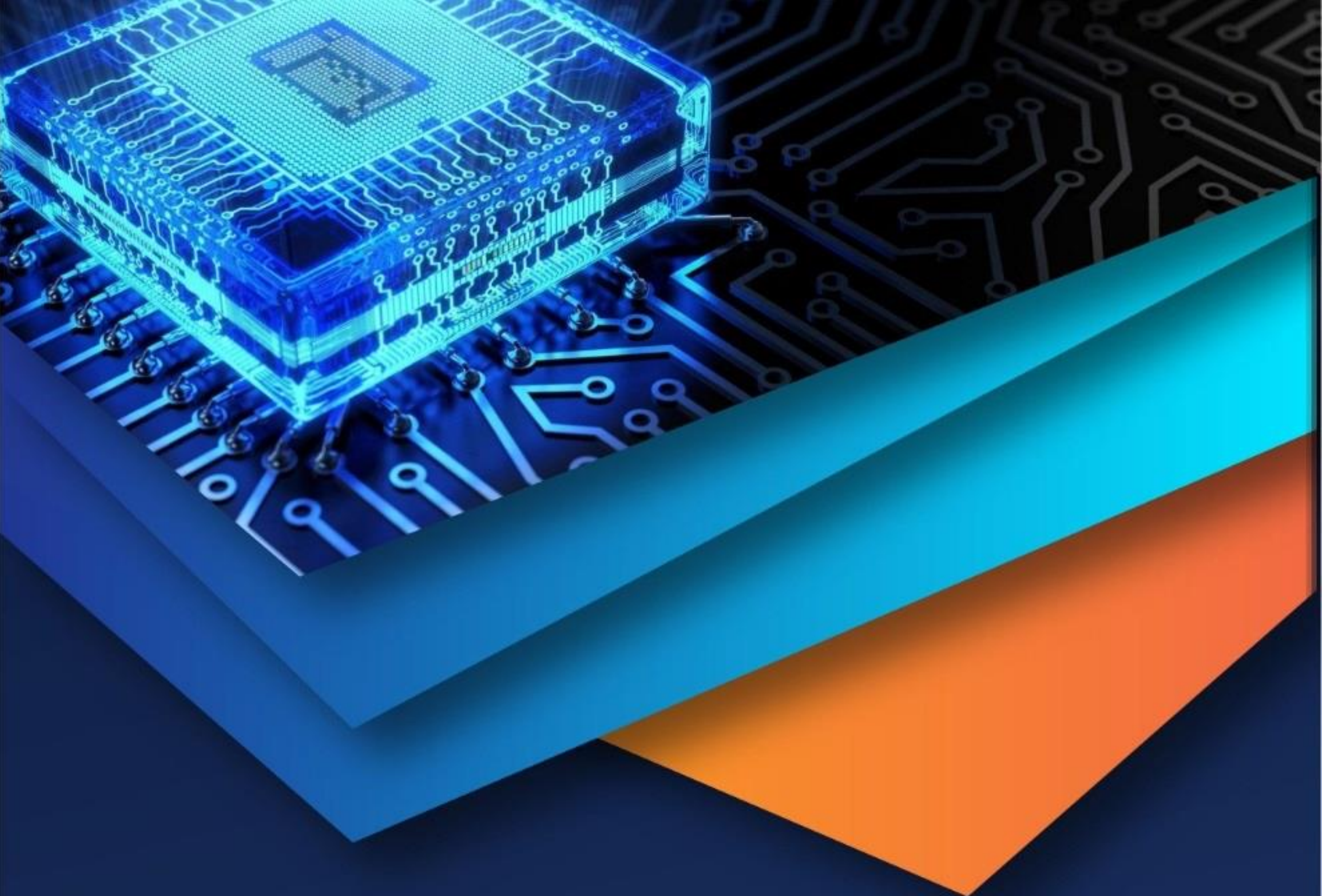

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