

# A Cloud-Integrated Wireless Sensor Network for Flexible and Long-Term Environmental Monitoring

*S.Senkalvarayan<sup>1</sup>, Assistant Professor, Tittagudi Sengunthar Engineering College.*

*M.Karunamoorthy<sup>2</sup>, Assistant Professor, Tittagudi Sengunthar Engineering College.*

*M.Jayasri<sup>3</sup>, Assistant Professor, Tittagudi Sengunthar Engineering College.*

**Abstract:** Environmental monitoring is extremely important to ensure a safe and wealthy life of both humans and artifacts. Monitoring requirements are extremely different depending on the environment, leading to ad hoc implementations that lack flexibility. The solution is based on small autonomous wireless sensor nodes, small wireless receivers connected to the Internet, and a cloud architecture data storage and delivery to remote clients. To have an immediate idea of current situation by using their smart-phones but also to monitor remote site the Internet. All measurements are redundantly stored at different concentration guarantee a safe back-trace and to provide. The sensing node shaves small impact, with dimensions of less than 2.5 cm× cm when the nodes have to acquire only temperature and relative humidity, and a low cost set-and-forget way for intervals in excess of one year.

**Index**      **Terms—Environmental monitoring, history, measurement techniques, quality assurance, wireless sensor network.**

## I. INTRODUCTION

Environmental monitoring issues and architectures are deeply investigated in the literature, and the interest of the instrumentation and measurement community for topic is highlighted also by the establishment of a specific technical committee.

Several papers deal with the development of low-cost monitoring networks, most of them focused on home applications, on Sensor development, and on network aspects. However, less attention is paid to the monitoring of climate parameters inside heritage buildings and museums where only noninvasive systems can be employed in order to avoid any impact on the visitor fruition and on the aesthetic appearance of showcases and rooms. Furthermore, monitoring is not an end in itself, but it is a means to find out what the environmental conditions are and whether they have to be controlled to ensure the long-time reservation of the artifacts.

## II. PROPOSEDSYSTEM

*Fig.1.1. Block diagram of the proposed architecture with three-level data storage.*

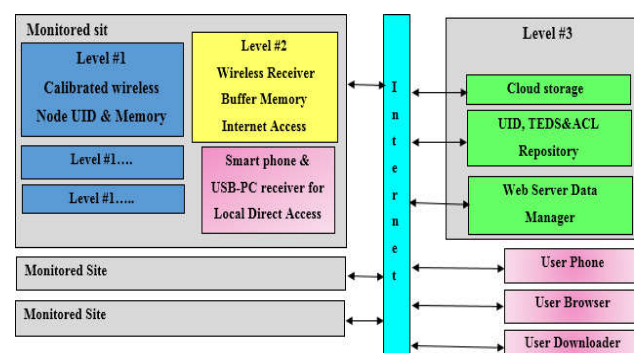
Nowadays several solutions for monitoring different environmental parameters, based on wireless nodes, have been proposed. The solution described in this paper, even though conceived with a similar approach, pays particular attention to the data storage and safety. The proposed architecture relies on a three-level data storage, which provides a strong data safety. In particular it gives the possibility to retrieve the whole measurement history of the monitored site, avoiding any issue connected with cabling and network connection break.

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## III. BLOCKDIAGRAMDESCRIPTION

### A) Level1

It is represented by the sensor nodes. The nodes, described in detail in Section 2.3, have the peculiarity of embedding a local nonvolatile memory for storing all measurements and raw data collected by the sensors during the network operative state. Each node has a unique identifier data(UID)which is written inside the firmware and cannot be changed. The firmware is designed to never over write the measurements



stored in the local memory. After the battery is installed, the node starts measuring at 15 min intervals storing the measurements into the memory. At this pacing, the local nonvolatile memory has the capability of storing data for up to 3 years, which is also the expected life of the battery. It is not possible to tamper with the measurements unless a physical access to sensor is provided. The firm ware lets users change only the measurement timing. Even when the battery is completely discharged, it is still possible to retrieve the measurements by connecting the sensor circuit to a proper programming board. Each node, after manufacturing, is calibrated by direct comparison with reference sensors. All calibration constants are used to arrange a transducer electronic data sheet (TEDS), which is associated with sensor UID and stored in the remote cloud memory. The calibration data are not stored in the node firmware so that each node can be recalibrated and/or checked without altering its firmware or interfering with the ongoing measurement. Even though this approach requires the users to access the remote cloud repository in order to obtain the best node accuracy, it is intrinsically safe with respect to any kind of hacking. In the absence of TEDS access, users can still compute the relevant quantities by using the nominal sensor constants, so an approximate estimation can be always obtained. The nodes have wireless capability thanks to the Bluetooth low energy (BT-LE) protocol, which hallows ending all data to a receiver up to a distance of at least 10m.

### **B) Level2**

It is represented by the receivers, usually one per room, which act as the bridge between the sensing nodes and the Internet. The receivers are able to gather data from all the measuring nodes, which are within their receiving range, and to send them to the remote storage via an Internet connection. Since they have to remain online to transmit the measurements in real time, they need to be continuously connected to a power supply. The receivers have their own UID and are battery backed so they can also work if the power supply goes off for a maximum of three days. They implement also a local storage where the measurements sent by the nodes are stored till it is possible to deliver them to the remote

repository. This way the data transfer over the Internet can be deferred for a few days in the case a connection cannot be established. Using this buffer memory increases the possibility of delivering the measurements to the remote repository even though a connection channel is available only on an intermittent basis, like in the case of phone-assisted data traffic.

### **C) Level3**

It is represented by a distributed cloud storage. All data from all nodes are stored into a cloud database and can be retrieved by authorized users. Apart from the storage, the picture shows two important functions as separate blocks. The first block is represented by the UID, TEDS, and access control list (ACL) repository. It stores the node conditions, the last data sent to the cloud, the calibration constants and the results of any periodical recalibration to assure the quality and reliability of the measurements. In addition, this block plays also an important role in defining the user access rights, via the ACL manager. As explained later, each user is granted the possibility of seeing data coming from specific receivers so the users are free to add and move nodes which are within the receiver range. Should the receivers have a problem, as an example due to a not functioning network, and an administrative action is required to download data directly from the nodes, such data are inserted into the database on behalf of the receiver and made available to the users. The second block is represented by the Web Server data manager that actually lets users access the node measurements. The server can arrange web pages to show selected data, identified by UID and time intervals, to the authorized users. The authorization structure allows also for the possibility of granting partial data visibility to additional. Users with specific credentials or either to all users without authentication, if required.

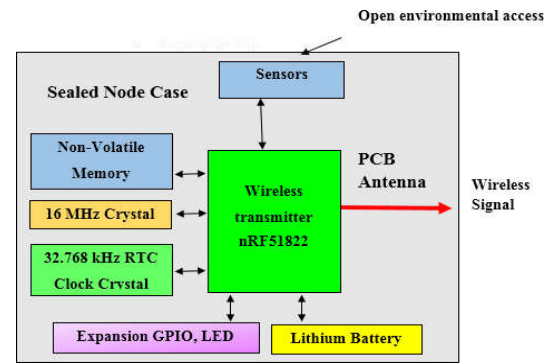
## **IV. MEASUREMENTNODES**

Most of the commercial environmental monitoring systems are not designed for

Guaranteeing data quality and reliability. In fact, most miniaturized sensors do not provide at the same time both a local memory for data storage and a wireless link for data transmission. The proposed node architecture instead stores all the measurements in its local memory voiding any possible data loss in case of failure in the wireless link or in the Internet connection. Connection failures can occur frequently in cultural heritage sites where the power supply could not be always available or the Internet link could be unreliable and slow. Some miniaturized data loggers commercially available embeds local memory, but usually its capacity is limited to few thousands of measurements. As an example, the Thermochron/Hygrochron I Button produced by Maxim Integrated, provides a storage capacity of only 2048 measurements, and the tiny data logger MicroT by Phase IV Engineering Inc., allows storing no more than 4000 measurements. Other similar data loggers are the MicroLog Pro II and the OM-90. However, none of these systems implement a long-range wireless data link and all require users to actively operate to download measurement data.

#### In particular, the following holds:

- 1) Long operative life without any required attendance;
- 2) No cabling for node placement and wide wireless range;
- 3) Flexibility in the deployment, management, and operation;
- 4) Capability of working also in the absence of power supply or Internet connection;
- 5) On-board backup nonvolatile memory avoid any possible data loss;
- 6) Data quality assured by calibration;
- 7) Local and remote data access and control using the extensive cloud infrastructure and  $\mu$  Panel architecture;
- 8) Low cost, small size, and minimal invasiveness.



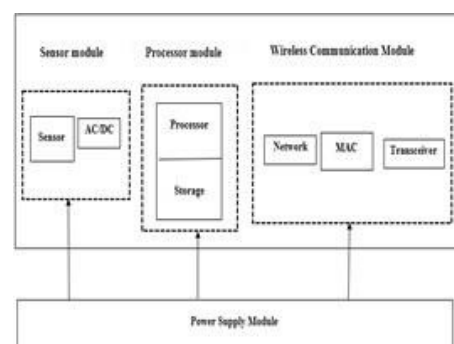
**Fig.4.1. Block diagram of the realized sensor node.**

#### A. Node Architecture

The block diagrams of the sensing node architecture is shown in Fig.2. The figure shows the following.

- 1) The node core based on the System-on-Chip (SoC) nRF51822, manufactured by Nordic Semiconductor. This chip integrates a 32-b ARM-M0 microcontroller, a low-power 2.4-GHz transceiver, and a large set of peripherals including an analog-to-digital converter which can be useful for interfacing analog sensors.
- 2) The nonvolatile flash memory W25X40CL manufactured by Win bond, which is connected to the microcontroller via the serial peripheral interface. The memory is powered on-demand in order to reduce the power consumption and provides the node with a 4 Mb on-board memory for measurement data storage.
- 3) The lithium battery, which is directly soldered to the printed circuit board (PCB) to power the node for its entire operative life.

The antenna for the wireless communication between the node and the receiver. The nodes employ a node.



**Fig.4.2. Sensor Node Architecture**

## B) Communication Protocol

The RTC wakes up the node periodically in order to perform the measurements. All results are stored inside the nonvolatile memory and sent to a receiver. In the case a compatible receiver is in the transmission range, it responds to the node with as can request, that is used as a sort of acknowledge. If the receiver UID is recognized, the node marks the data as received but avoids sending any scan response in order to reduce power consumption. If no receiver responds to the node advertising, the node continues performing the measurements as set, storing their values inside its memory as non-received. When a recognized receiver acknowledges the node advertising, the node starts sending alternately the last measurement and the old one until all data in the memory are marked as received.

In order to avoid the disclosure of sensible data to unauthorized people, it is possible to encrypt transmitted data. In addition, it is possible to set the node to connect only to specific UIDs with a further reduction of the power consumption. The authorized receivers can connect and use a normal transfer communication in order to either quickly retrieve data or reconfigure the sensor node.

## V. RECEIVERS

The two main ways a generic user can employ for receiving data from the nodes: a dedicated BT-LE wireless receiver connected to the Internet, and a compatible smart phone taken close to the nodes.

### A. Dedicated BT-LE Receiver

This type of receiver can be employed when the monitored location is provided with a power supply and an Internet connection (e.g., a Wi-Fi Network). In this situation, the receiver stays always connected to the Internet waiting for the sensor data. When a new measurement is available, it gets such measurement and pushes it on the cloud infrastructure. This allows either a real-time or a quasi-real-time monitoring of the location with data available worldwide.

If an Internet connection problem occurs preventing the receiver to access the Internet, the receiver is able to temporarily store measurements inside a dedicated buffer, waiting for pushing them on the cloud as soon as the Internet connection is again available. The possibility of short power blackouts is managed by providing the receiver with a backup battery that can power the system up to few days. If the power absence lasts longer, the receiver shuts down. Nevertheless, measurements are anyway stored on node memories, so they can be retrieved either directly or upon a cloud request, without any loss.

### A) Sensor Network Characteristics

A mobile ad-hoc network is composed of a ten to hundreds of nodes. The aim is to transmit multimedia information flow with service quality requirements through dynamic routing and mobility management technology. Usually, a node has a constant energy supply. Although sensor networks and wireless ad hoc networks are similar, there are also significant differences. A sensor network is an integrated monitoring, control and wireless communication network system with much larger number of nodes (thousands or even tens of thousands) and the node distribution is more intensive. The nodes could make an error because of environmental impact and energy. In addition, the sensor node's energy, processing power, storage capacity and communications capabilities are all very limited. The primary design goal of traditional wireless networks is to provide high quality and efficient bandwidth utilization, followed by considered energy savings. The primary design goal of sensor networks is the efficient use of energy, which is the main difference between sensor networks and traditional networks.

### A) Power Energy Limited

Usually the sensor node just carries a very limited battery power because the nodes are very small. The method of recharging by changing the battery is not realistic because the numbers of sensor nodes are huge, and the distribution is wide and complex and, some regions cannot be reached by person



Efficient use of energy to maximize the network life cycle is the most important challenges of the sensor networks. Sensor node consumes energy modules include 3 modules which are sensor modules, processor modules, and wireless communication module. With advances in integrated circuit technology, the processor and sensor modules consume very little power and most of the energy consumption occurs in the wireless communication module. The sensor node 10 transmitting information consumes more power than the implementation of the calculation. The energy consumption of transmitting one bit of information to 100m distance is equal to the power consumption of operating 3000 calculation instructions.

### B) Limited communication capabilities

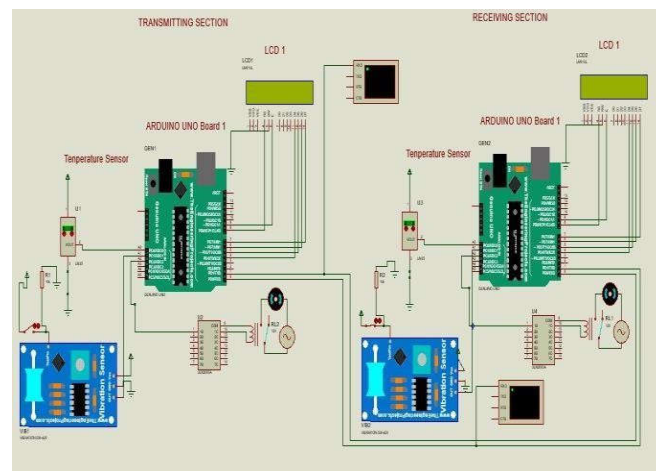
The relationship of wireless communication and communication distance is expressed as:

$$E = kdn$$

\* E: Energy consumption, K: Constant, D: distance the parameters satisfy the relation  $2 < n < 4$ . The values of n are related to many factors, such as sensor nodes deployed close to the ground, many obstacles interferences, the impact of signal transmission will be larger when n's value is large. With the increase in communication distance, energy consumption will increase dramatically. Therefore, the communications connectivity should be minimized under a single hop communication distance. In general, the wireless communication radius of sensor nodes should be within 100m. Considering the energy constraints of sensor nodes and large network coverage area, the sensor network should use multi-path routing as the main transport method. The bandwidth of Wireless sensor nodes are limited, usually only a few hundred kbps rate. The wireless communication might be changed usually because the environment changes. One of the main challenges of a sensor network is designing a suitable network communication method.

## VI. SIMULATION

### A) CIRCUIT DIAGRAM



*Fig.6.1.Arduinocircuitdiagram*

They can be two different types of machines when the temperature sensor can be increased when the vibration sensor is vibrating to the machine. Then the two switches consists of machines one switch is open and an others witch is closed. Temperature is increased into LCD board display then value scan be changed in low to high. Transmitting section is passing through the values reviving section.

### B) SIMULATION RESULT



*Fig.6.2 Simulation Result of Machine1*

## VII. OVERVIEW OF ARDUINO BOARD

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino boards.



*Fig. 7.1. overview of Arduino Board*

## VIII. CONCLUSION

Environmental monitoring is a tricky activity as the environmental conditions can easily change from point to point even at small distances. This is especially true inside buildings where temperature, humidity, and pollutants can be different not only in different rooms but also within the same room especially when showcases and closed furniture are used. The multilayer data storage system with battery-operated sensors equipped with a local nonvolatile memory and a transmission protocol, case of network failure.

The proposed architecture has been deployed in several heritage buildings and museums and is producing measurements since 2015 with about 50 nodes already installed.

The area of sensor network has a long history and many kind of sensor device are used in various real life applications. Here, we introduce wireless sensor network which when combine with an important role in analyzing the data of forest temperature, traffic control, telecommunication etc.

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