Smart-IoUT 1.0: A Smart Aquatic Monitoring Network based on Internet of Underwater Things (IoUT)

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Abstract:

Keywords:

1 Introduction

The planet earth is also referred as "*Majestic Blue Marble"* due to prevalence of water on the earth's surface. In other terms, 71% of the earth's surface is covered with water and rest 29% is continents and islands. 96.5% of earth's water is ocean's salt water and only 3.5% remaining is fresh water and other lakes and glaciers. Wireless transmission of information via oceans is one of the enabling technologies laying strong foundation for the development of ocean-observation systems, smart underwater sensor network (UWSN) and even future oriented Internet of Things enabled UWSN i.e. IoUT. New technologies have enabled new ways for monitoring and sensing aquatic environments via sensors. Underwater sensing has led to diverse applications ranging from simple aquaculture to oil industry and also includes monitoring of river and sea pollution, oceanographic data collection, natural disturbances prediction, conducting search-survey-rescue missions, marine life study and surveillance. Accordingly, Underwater Sensor Network [1] is highly emerging technology for carrying out all underwater operations. UWSN is regarded as fusion of Wireless Technology and Smart Sensors with MEMS capability having smart sensing, computing and communication capability. UWSN is defined as "*Network of Autonomous Sensor Nodes operating Underwater spatially distributed to sense water related parameters like Temperature, Pressure, Oxygen Level and other underwater monitoring".* The sensed data is communicated back to base station utilized by human beings for diverse research, analysis and other sorts of operations. The sensor nodes operating underwater are either fixed or mobile and connected via wireless communication modules to transfer data. Underwater Sensor Network operates in a scenario where set of wireless nodes after acquiring the data transmit the data back to buoyant gateway nodes and gateway nodes relay the data back to control and monitoring station called Remote Station. Underwater Sensor Networks are classified into four different architectures which lays foundation for designing UWSN applications: 1D-UWSN, 2D-

UWSN, 3D-UWSN and 4D-UWSN [2]. 1D-UWSN architecture defines autonomous deployment of underwater nodes where every node operates in standalone position and solely responsible for performing all tasks of sensing, processing and transmission back to remote station. Example: AUV (Autonomous Vehicles) diving underwater, performs sensing and collecting information and transmits the information back to remote station. 2D-UWSN architecture, defines UWSN sensor nodes deployed underwater in form of cluster. Every cluster consists of cluster head i.e. Anchor Node. All nodes collect data and relays back to anchor node via Horizontal link communication and anchor node, in turn, relays data back to surface buoyant node via Vertical link communication. 3D-UWSN, sensor nodes are deployed like 2D-UWSN in cluster manner at varied depths and communication happens in three forms- InterCluster-Nodes communication; IntraCluster- Nodes and Anchor Node Communication; Anchor-Buoyant communication. 4D-UWSN architecture is combination of 1D, 2D, 3D UWSN architecture and comprise of Remotely operated Underwater vehicles. Fig 1 demonstrates 1D, 2D, 3D and 4D-UWSN architectures.

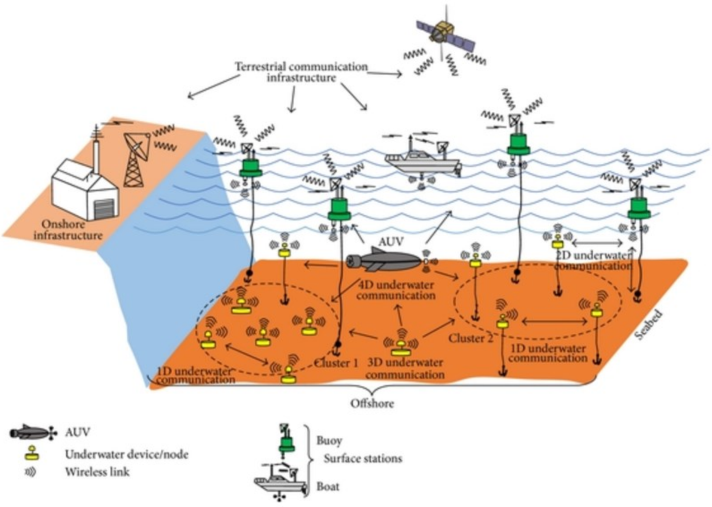

Fig. 1: Underwater Wireless Sensor Networks- Architecture

In recent years, lots of extensive interest with regard to modification and enhancement of Underwater Wireless Sensor Network, Smart Cities and Internet of Things (IoT) is observed and lots of researchers are working towards making Underwater Sensor Network compliant with Internet of Things (IoT). With use of IoT, UWSN and Smart Sensors cum Tracking Technologies, IoUT is developed. The objective of this research paper is to propose Smart IoUT- A smart IoUT based aquatic monitoring network equipped with lots of UWSN sensors for live monitoring. To the best of our knowledge, this is the first Smart IoUT 1.0 proposed for Live Underwater Sensor Monitoring with IoT capabilities.

Structure of Paper

The paper is structured as follows: Section 2 discusses of Internet of Underwater Things (IoUT)- Evolution, Introduction, Architecture and Challenges surrounding IoUT. Section 3 gives detailed overview of Smart IoUT 1.0- A Novel IoUT based solution designed for monitoring underwater environment- Basic Introduction, Components- Hardware and Software used and shreds light on Circuit and Working of Sensor Nodes. Section 4 gives detailed Overview of Smart IoUT 1.0 as well as sensor results captured from live underwater operational environment on thingspeak.com. Section 5 concludes the paper with future scope.

2 Internet of Underwater Things (IoUT)

2.1 Evolution and Introduction

Internet of Things (IoT) [4] was first defined by Kevin Ashton to lay foundation of how IoT can be developed by "adding RF-Identification and other sensors to everyday objects". With passage of time, IoT has gone to the next level and consists of network of entities i.e. Physical Objects, Home Appliances, Watches and any other devices embedded via electronics, software, sensors, actuators and connectors enabling data exchange. As per latest report by Ericsson, 29 Billion devices will be connected to Internet by 2022 out of which 18 Million will be IoT complaint and every year since 2016, IoT is increasing at rate of 21%.

With IoT, UWSN and Smart Sensor cum Communication technology, underwater monitoring can go to next level. IoT has facilitated the design of underwater wireless sensor network termed as IoUT. The term "IoUT" was first discussed by Mari Carmen Domigo in paper titled "An Overview of the Internet of Underwater Things" in 2012 [5]. IoUT is defined as "*World-Wide Network of Interconnected Smart Underwater objects with digital entity capable of sensing, processing and transmitting information to remote stations with combination of smart tracking technologies, Internet and Intelligent Sensors".*

The following Figure 2 gives overview of Internet of Underwater Things (IoUT) network:

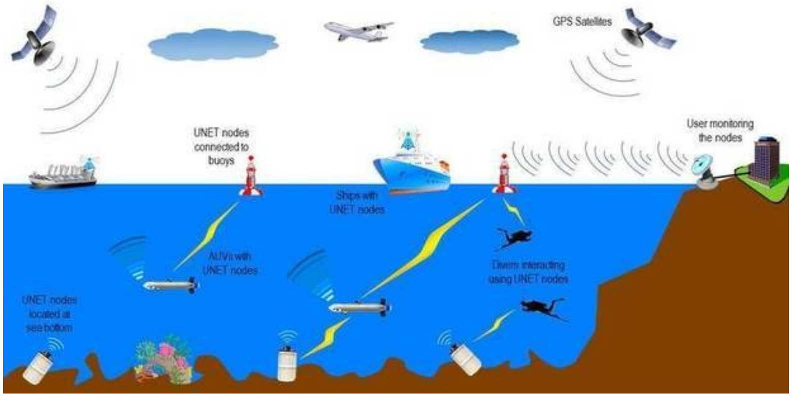

Fig. 2: IoUT Network

IoUT can also be defined via following formulae:

IoUT= Underwater Wireless Sensor Networks + Internet + Tracking Technologies + Smart/Intelligent Sensors

With Internet of Underwater Things (IoUT), underwater sensor monitoring has become more efficient and promising. The following three reasons highlights the strong reasons for the design and development of IoUT:

- With 71% of the planet earth covered with only water, researchers, ocean scientists and marine biologists believe still more than 60% of the area is unexplored. For diverse explorations and wide area monitoring, IoUT can play a smart role.
- IoUT lays a strong foundation for deploying smart and autonomous sensors especially mobile sensors for wide coverage, sensing lots of underwater properties and even marine life precision monitoring.
- IoUT can be utilized for diverse applications like Military to defending attack, underwater natural disaster monitoring, unlocking lots of ocean secrets and aquatic life new species discovery.

2.2 Architecture

Figure 3 demonstrates a standard Internet of Underwater Things (IoUT) architecture.

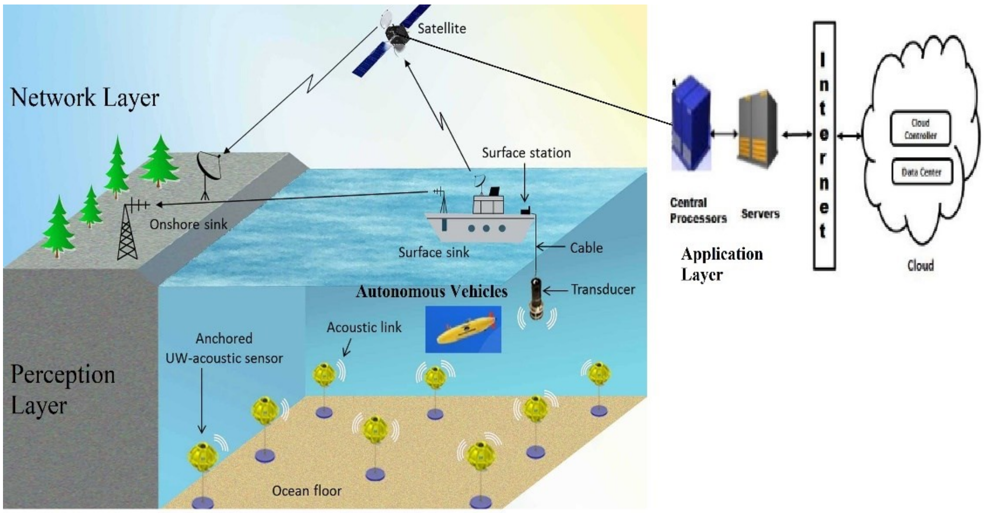

Figure 3: Standard IoUT Architecture

IoUT, typically, consists of three layers:

- Perception Layer: Perception layer comprise of all Underwater Sensor Nodes, Underwater Autonomous vehicles, Surface Links and all sorts of monitoring stations. The primary objective of this layer is to collect diverse amounts of information of underwater like underwater objects, aquatic life and all other properties of water.
- Network Layer: Network layer tasks is to acquire and process information received from the perception layer. This layer comprises of all wired as well as wireless links, cloud platform, internet and even remote connected servers for storing information.
- Application Layer: It consists of front-end applications which act as GUI interface to see the sensed information in form of data and gives user the desired end results of the information acquired.

2.3 Challenges of Internet of Underwater Things (IoUT)

Internet of Underwater Things (IoUT) is a fusion of Underwater Wireless Sensor Network and Internet of Things (IoT) technology. So, obviously, like UWSN and IoT, it is also surrounded by tons of challenges currently present in UWSN and IoT. In this section, some of the challenges surrounding IoUT are enlisted [6]:

1. Energy Efficiency: Energy utilization is one of the first and foremost challenging issue surrounding all types of sensor networks and even IoT objects. In order to operate underwater, communication systems and sensor nodes require more power and transmission distances in IoUT are very large, so high transmission power is required. In order to make the sensor nodes, operate

for long periods of time, energy efficient algorithms are required especially designed for IoUT as traditional and proposed energy solutions existing for UWSN cannot be suitably adapted for IoUT considering the requirement and speed of energy harvesting of the nodes.

2. Security: Lots of malicious attacks can be possible in underwater aquatic environment because of high bit error rates, low bandwidth and high propagation delays, this in turns, impact the link quality of underwater communications and impact overall connectivity. As underwater sensor nodes consume more energy during transmission, energy exhaustion attacks can even impact adversely over nodes and reduce the overall network lifetime of IoUT.
3. Mobility: For any UWSN network, all the sensor nodes operate in mobile condition. Underwater is impacted via water currents at short durations repeatedly, which changes the network topology of underwater operational nodes. Same mobility issues can even impact IoUT and can impact the overall network operation. Suitable and specifically designed mobility models are required for IoUT for break-free operation.
4. Lack of Standardization: IoUT has a stringent requirement of standard architectures to address interoperability issues between heterogeneous underwater systems. Currently, there exists NO de jure or de facto standard for IoUT. This makes heterogeneity of devices, technologies and services quite challenging. There is a strong requirement for development of novel protocols for IoUT to provide interoperability between heterogeneous underwater objects. In addition to this, gateways are required to facilitate communication between underwater sensors and IP-based networks.
5. Transmission Speeds & Propagation Speeds: Like in UWSN, where the transmission rate is near to 10 Kbps and bandwidth wastage is usually reported in UWSN. Same, is the case with IoUT, less transmission speeds impact overall performance. Considering propagation speed of UWSN which is near to about 1500 m/s, which is quite low, IoUT will face serious issues with regard to End-to-End delay.

3 Smart IoUT 1.0- A Smart Aquatic Monitoring Network based on Internet of Underwater Things (IoUT)

3.1 Definition & Brief Overview

Smart IoUT 1.0 is regarded as Smart Aquatic Monitoring Internet of Underwater Things (IoUT) based solution for monitoring various pedagogies of water like Dissolved Oxygen, Temperature, Water Turbidity and pH level. Smart IoUT 1.0 integrates the concept of Underwater Wireless Sensor Network (UWSN) and Internet of Things (IoT) with the objective to measure the water quality monitoring for lakes, rivers etc. with smart sensor nodes. Smart IoUT 1.0 is based on the concept of “Plug-Play-Sense” where the entire kit can just be sent to the water by starting up and sensors will sense the real-time data. The device is highly cheap, operational efficient, lightweight and even makes use of Solar Power technology for efficient energy harvesting. The device is tested in live condition on MyKhe Beach and Da Nang beach during early morning and late evening and Smart IoUT 1.0 has give almost 99% efficient data readings as compared to high cost and other IoUT based devices available in the market.

3.2 Components used

Components that make up Smart IoUT 1.0 for underwater monitoring are listed as follows:

3.2.1 Hardware Components

a. NodeMCU ESP 8266 Development Board: The NodeMCU is SoC-Based ESP8266 Wi-Fi chip development kit with easy interface design and makes use of Arduino compiler for programming and coding. The board integrates GPIO, PWM, IIC, 1-Wire, ADC, USB TTL and PCB Antenna.

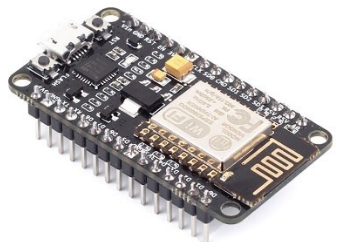

Fig 4. NodeMCU ESP8266 Development Board

b. TP4056 Charger: TP4056 is efficient constant current charger for LiPo/Li-ion batteries. It is highly efficient in utilization especially portal applications because of low external component count and small outline package. It has unique features like Automatic recharger, under voltage lockout, current monitor and 2 LED’s for charging mode and termination signal. It uses 5V-input voltage, 4.2 V charging voltage and 1A charge current.

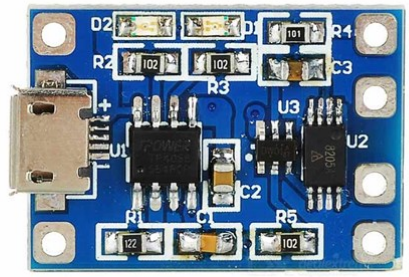

Fig 5. TP4056 Charger

c. Arduino Nano

3.2.2 Sensors

a. Atlas EO Dissolved Oxygen Kit: The Dissolved Oxygen Kit acquires data and give the results in form of Mg/L. It bundles everything to take precision, full range D.O. readings for environmental monitoring, wine making, fish monitoring etc.

Technical Specifications: Full oxygen readings range from 0.01 to +35.99 mg/l; precision dissolved oxygen reading with accuracy +/- 0.2; Temperature compensation; Salinity Compensation; Pressure compensation; UART; I2C; HDPE dissolved oxygen probe and operating voltage 3.3v to 5v.

Fig. 6. Atlas EO Dissolved Oxygen Kit

b. DS18B20 Temperature Sensor

DS18B20 Temperature sensor provides Celsius temperature measurements with 9 to 12-bit precision. The DS18B20 has 64-bit serial code which allows multiple DS18B20s to function on same 1-wire bus.

Technical Specifications: No external components; converts temperature to 12-bit digital word in 750ms; operational in different form factors like Body Temperature and even underwater.

Fig. 7 DS18B20 Temperature Sensor

c. Analog Turbidity Sensor

Analog Turbidity Sensor is capable to detect water quality by measuring turbidity level. This sensor is able to detect suspended particles in water by measuring light transmittance and scattering rate which changes relative to the amount of total suspended solids (TSS) in the water. With the increase in TSS, the liquid turbidity level increases. The sensor is highly efficient to determine the water quality in swimming pools, rivers and other laboratory-based measurements.

Technical Specifications: Response Time: <500ms; Analog Output – 0-4.5 V, 100M Insulation Resistance, Operating Temperature: 5^{o}C to 90^{o}C, Operating Voltage: 5V DC.

Fig 8. Analog Turbidity Sensor

d. pH Sensor: pH= Hydrogen. pH sensor is used to determine the hydrogen level of the water. It consists of an LED as Power Indicator, BNC Connector and is well connected with Arduino controller via analog input port.

Technical Specifications- Measuring range: 0-60^{o}C, Response time<1min; measuring range 0-14PH; 5V power.

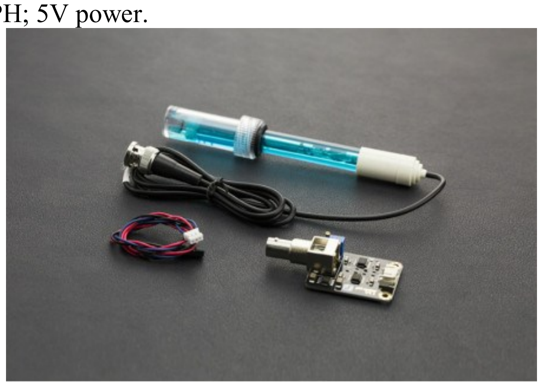

Fig 9. pH Sensor

3.3.3 Software

a. Arduino IDE Environment: Arduino IDE is a platform independent base for Arduino hardware and can run on multiple operating system platforms. It consists of text editor for code writing, message area, text console and a toolbar with common functions and menus. It can connect to all sorts of Arduino Boards for uploading programs and communication with boards. Programs in Arduino IDE are written as sketches with file extension .ino and IDE provides strong interface by displaying all error messages and other information.
b. Thingspeak.com : It is an open source IoT Application and API to store data received from sensors and makes use of HTTP protocol to display the results in form of graphs. It is powerful IoT platform to provide aggregation, visualization and analysis of live data in cloud. It enables device configuration to send data to thingspeak.com using REST API or MQTT.

3.3.4 Architecture

Smart IoUT 1.0 consists of two sensor nodes: Node 1 and Node 2. In this section of research paper, the entire circuit of Node 1 and Node 2 making Smart IoUT 1.0 is highlighted.

Node1

Node 1 consists of two sensors: Temperature Sensor: DSB1820 and EZO Dissolved Oxygen Sensor. The following Table 1 highlights in details of Node 1.

Node	Hardware	Unit	Amplitude
Node 1	Solar panel	V	0-9V
	Tp4056 charger circuit		
	NodeMCU ESP8266 development board		
	Atlas Scientific DO kit		
	Battery 5v 2000mAh	V	2000mAh
	EZO Dissolved Oxygen Sensor	mg/L	0.01 – 100 mg/L
	DS18B20 temperature sensor	°C	-55°C to +125°C

Table 1: Node 1 Technical Specifications

The following Fig 10 highlights the General Working of Node 1 in Smart IoUT 1.0

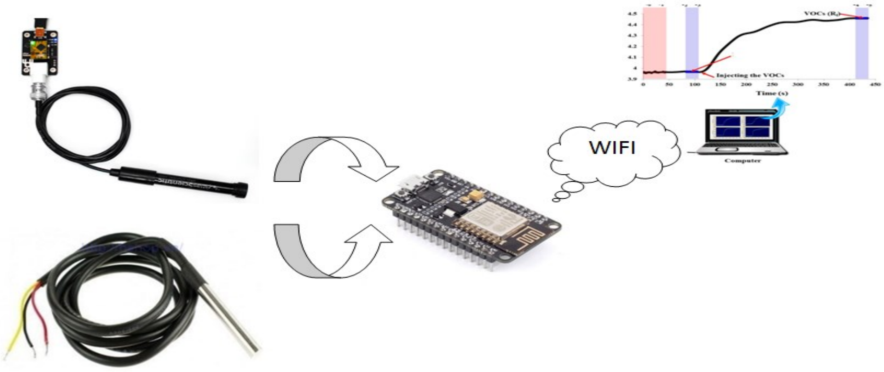

Fig. 10 Node 1- Smart IoUT 1.0

The Following Fig 12 highlights the Circuit Diagram of Node 1.

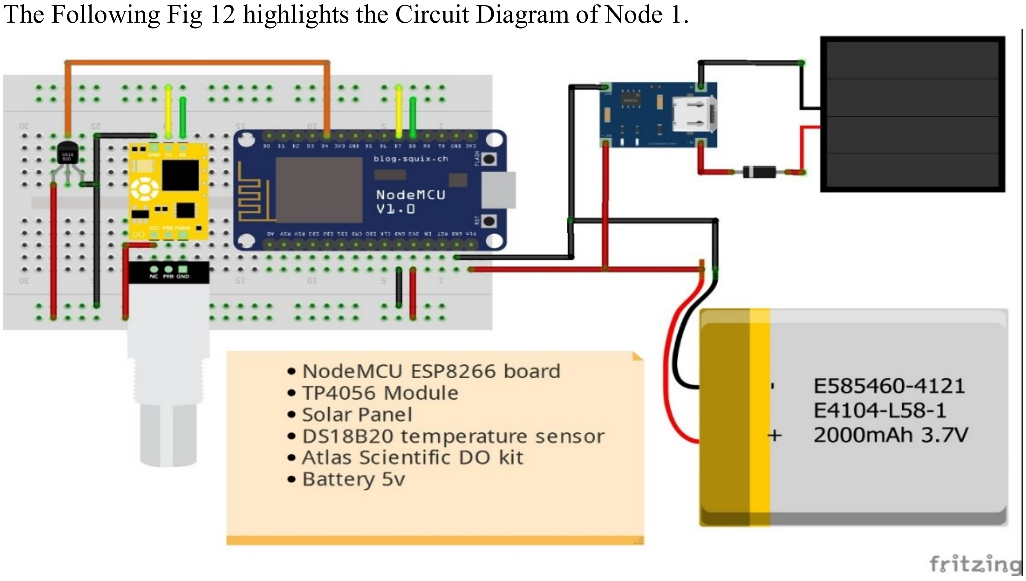

Fig. 11 Node 1 Circuit Diagram

Node 1 makes use of NodeMCU ESP8266 as the central processor. It reads the temperature via DS18B20 Temperature sensor and oxygen concentration using EZO Atlas Scientific DO kit.

Node 2

Node 2 consists of two sensors: Water Turbidity Sensor and pH Sensor. The following Table 2 highlights in details of Node 1.

Node	Sensor	Unit	Amplitude
Node 2	Water Turbidity Sensor	NTU	0-3000
	PH Analog	PH	0 -14
	Solar panel	V	0-9V
	Tp4056 charger circuit		
	NodeMCU ESP8266 development board		
	Battery 5v 2000mAh	mAh	2000

Table 2: Node 2 Technical Specifications

The following Fig 13 highlights the General Working of Node 1 in Smart IoUT 1.0

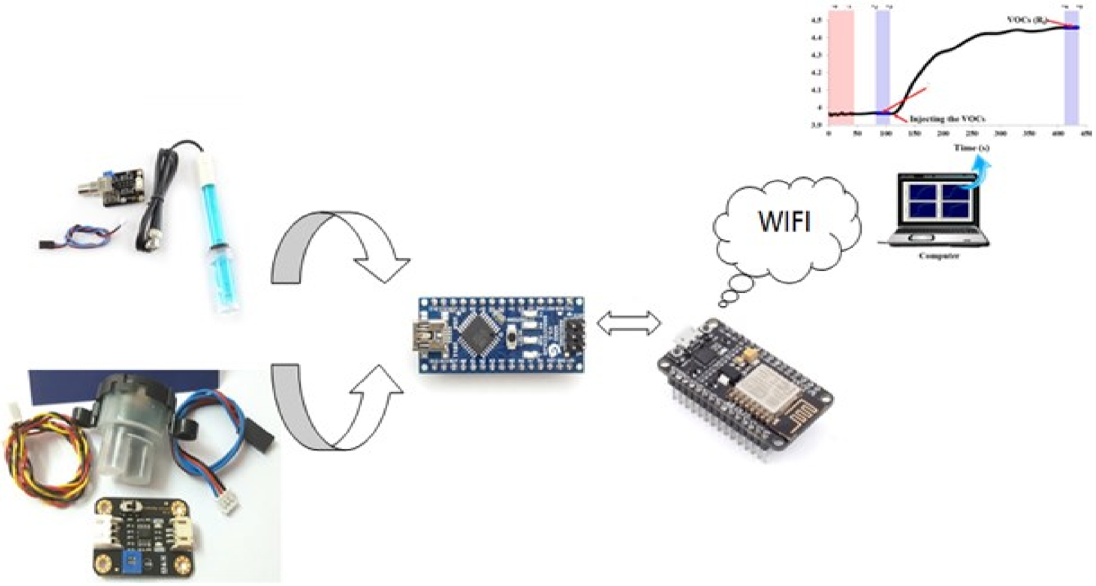

Fig. 12 Node 2- Smart IoUT 1.0

The Following Fig 14 highlights the Circuit Diagram of Node 2.

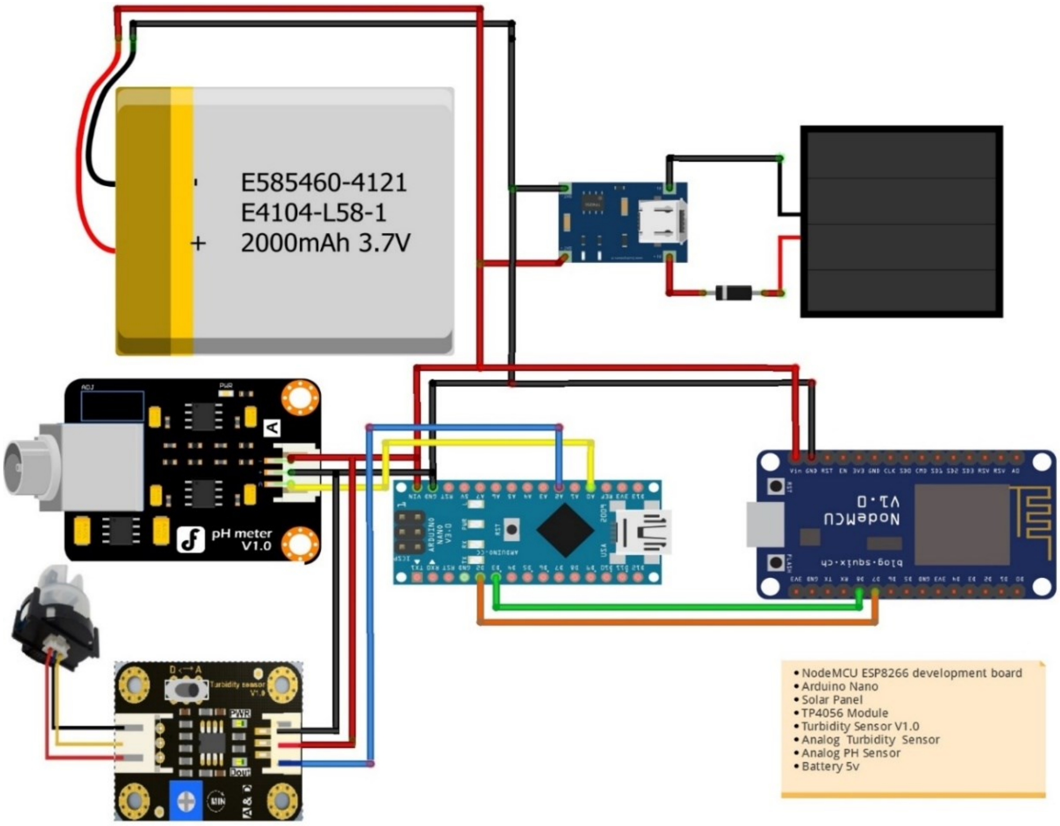

Fig. 14 Node 2 Circuit Diagram

Circuit Explanation

4 Smart IoUT 1.0- A Smart Aquatic Monitoring Network based on Internet of Underwater Things (IoUT)- Working Prototype and Results.

In this section, Smart IoUT 1.0 for smart aquatic monitoring is discussed.

The following Fig 15 highlights the complete ready to use Smart IoUT-1.0 for live aquatic monitoring.


Fig. 15 Smart IoUT 1.0- Live Aquatic Monitoring


Fig. 16 Overall Architecture of Smart IoUT 1.0- Live Aquatic Monitoring

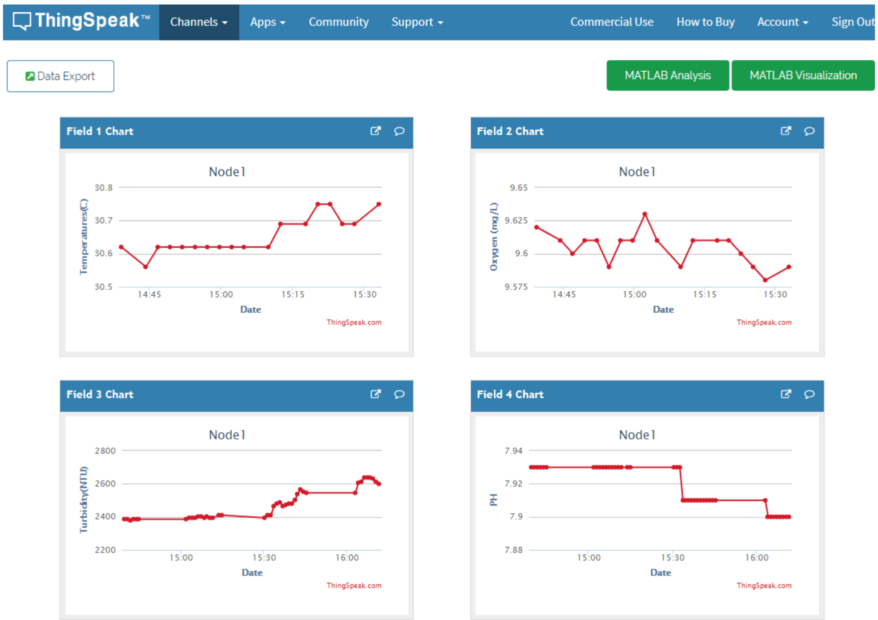

Fig. 17 Live Thingspeak.com Results- IoT Based Results- Temperature, Oxygen, Turbidity, pH level- Node-1 and Node 2

Section 4 shreds light on Circuit and Working of Sensor Nodes as well as in depth working of Smart IoUT 1.0- Flowchart. Section 6 gives sensor oriented based results captured from live underwater operational environment on thingspeak.com. Section 7 concludes the paper with future scope.

4.1 A Subsection Sample

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