

# Energy Harvesting for Water Quality Monitoring using Floating Sensor Networks: A Generic Framework

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## Abstract:

Water is a constrained asset and basic requirement for animals, cultivation and industry that exist on this Earth including mankind. Subsequently, to measure the characteristics like physical, biological and chemical attributes of water becomes indispensable. Floating sensor networks (FSN) with in-situ sensors are now widely used to gather the water quality data. The main goal that deals with FSNs is data reliability, congestion control, optimal node placement and energy. So far, we proposed a generic framework for energy harvesting, reliable data transform congestion detection and deployment strategy for FSN to collect water quality data. Energy harvesting subsystem model will be designed to fulfil the needs for the desired application scenarios in sensor networks and extend the network lifetime. Therefore, this model will help in scheduling the sending/receiving, sleeping and idle time of the node. By incorporating this framework, network lifetime can be prolonged. For reliable data transform and congestion detection; a model will be developed to enhance the data delivery. The objectives of optimal node deployment are full coverage, network connectivity, improve the data fidelity and enhance the network lifetime.

**Keywords:** *Wireless sensor networks; Floating sensor network; Water quality; Energy harvesting; Reliable data transfer.*

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## 1. Introduction

Water is the greatest blessing of Almighty Allah, so it plays a pivotal role for the survival of all living things. So, by keeping its importance we should understand its optimized usage. If we look around our surroundings, we can find that most of the people are unable to have good and hygienic water for drinking. Even most developed countries of the world are using filthy and

polluted water for in taking deprived of suitably treated. This condition happens due to shortage of water quality monitoring and treatment systems. There are various sensors available for the monitoring of water parameters, like pH, oxygen density, temperature, humidity, salinity and so on [1]. Hence, for improving the water quality, its key parameters must be calculated before going towards quality sector. Water quality parameters, like temperature, conductivity,

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turbidity, salinity, pH, dissolved oxygen and total dissolved solids are the most important parameters of water to be measured. As, we know that the quality of water totally relies on these parameters. Once these parameters are calculated then it becomes much easier to work on water treatment procedures.

The hasty and prompt advancement of technology in the field of wireless sensor network (WSN) has capability of developing a novel tool for data acquisition, environmental monitoring, wireless back-end transmission and so on in terms of real-time deployment and implementation. Wireless sensor networks are composed of various tiny components called as nodes [2]. Each node consists of desired sensors, memory, processor, radio frequency (RF) transceiver, antenna, etc. The WSN field is a broad field in terms of types and application scenarios [3, 4]. Various types of wireless sensor networks are terrestrial WSNs, underwater WSNs, underground WSNs, floating WSNs; mobile WSNs. Wireless sensor network also seeks applications in water bodies by incorporating a new emerging field, so called as floating sensor networks (FSN) [5, 6]. Floating sensor networks with *in situ* sensors are now widely used to gain the water quality data. Floating sensor networks that take local measurements and water flows in water bodies and rivers are formally called as drifters [5-7].

So far, our focus is to propose a generic framework with reliable data transform and deployed in real time based on FSNs to monitor the water quality parameters powered by harvested energy. Many researchers have already worked on sensor networks-based water environmental monitoring with [8-10] and without [11-14] energy harvesting mechanisms [15-21] like, radio frequency (RF), solar, wind, thermal and flow. Meanwhile, different researcher in the state-of-the-art have focused on reliable data transform [22, 23] to enable the maximum data transmission and congestion control and optimal deployment strategies [24, 25] by

addressing various deployment techniques such as, fixed, random, grid, hybrid and so on for sensor networks.

As for this proposed system, we will focus on measurement of parameters, such as temperature, conductivity, turbidity, salinity, pH, dissolved oxygen and total dissolved solids of water. For this, FSNs are excellent choice for monitoring different parameters and properties of water. The nodes will be equipped with these sensors and deployed into water bodies. These nodes will communicate via a wireless medium with sink node available at base station. For this task, various floating sensor nodes will be deployed fixed and randomly into water reservoirs. The nodes will be distributed for collecting the data and then transmit it via a prescribed wireless channel to base station and remote station for end user analysis. For continuous monitoring, energy harvesting mechanism will be provided. Solar and wind energy sources are incorporated to handle the power requirements. The harvested energy is stored in super capacitors and secondary batteries accordingly. To maintain the energy flow and ratings, an energy aware mechanism will be accorded. We also turn our focus on data transform by touching reliable data transfer and congestion control mechanisms and algorithms. A GUI tool will be designed for analyzing the results and statistics of water quality. There are two types of users for the analysis of water quality results, which are technical (experts and researcher) and non-technical people. For non-technical user, we will design a simple GUI tool for displaying the data.

### 1.1. Motivation

As Pakistan is populous country and it is facing huge water crises. So far, to overcome this issue we must take initially necessary steps for making water pure, for this; first the properties of water must be calculated to purify or improve its qualities. The water quality is an essential ingredient that plays a pivotal role for living organisms, their basic

needs and routine jobs, such as drinking, cooking, farming, etc. So far, this proposed system will be supportive to measure key parameters of water, which are necessary for the treatment of saline and soiled water. By measuring the key parameters, it will easily be arbitrated that whether this water is useful for drinking and irrigation or it would be treated. Hence, this proposed system will fulfil all these aspects and will be suitable to achieve this task.

### 1.2. Research Challenges

These research challenges will be faced during designing water quality monitoring system.

- FSNs are not suitable for continuous monitoring of water bodies/reservoirs, because they have limited life to measure the water parameters.
- The most significant challenge in the framework is interdependencies between the simulated scenarios and physical components of the system.
- There is no any sustainable energy mechanism for FSNs to collect continuous data.
- Energy harvesting subsystems are not easy to model in existing WSN simulators.
- Some realistic properties of the energy harvester are very challenging to implement in a simulator using a high-level programming.
- Design of complex algorithms for scheduling the different modes of the nodes like idle, sleep, sense, transmit, etc. to maximize the network lifetime and conserve more energy.
- Reliable data transfer in sensor network is a standout amongst the most essential issues.
- Significant resources are wasted when water quality data is missing, or instruments are not properly configured.

### 1.3. Contribution

Our contribution in this paper includes:

- 1) We have proposed a novel framework based on FSN for monitoring the water quality data.
- 2) In addition, we integrate energy harvesters into our framework for providing the continuous power supply. We also add super capacitors and batteries for storing the extra harvested energy. That can be used as a standby to cope the energy failure.
- 3) Next, we include a block for the reliable data transformation. This helps to maximize the data delivery ratio and curtails the packet loss ratio.
- 4) In last, an application is also suggested to get water quality data at remote or end users in terms of graphs and statistics.

In this study, paper organization is described as: section II covers the state-of-the-art. Problem statement is described in section III. In section IV, the research questions are addressed and the proposed generic framework for the system is described in section V. Section VI is all about the architecture of system and in addition, a novel architecture of FSN node to monitor the water quality data is also given. In section VII, the proposed methodology is illustrated. Expected outcomes in section VIII, Conclusion is given in section IX.

## 2. State of the Art

Here we discuss some existing work of different domain of research areas. In last, a comparative analysis is also given in TABLE I.

### 2.1. Floating Sensor Networks

A. Tinka, et al. (2013) [5] have presented a complete drifter system and acknowledged a pilot experiment in a controlled channel. The utility of the system for making

measurements in unknown environments is highlighted by a combined parameter estimation and data assimilation algorithm using an extended Kalman filter. These drifters were utilized to measure water quality data; DO, Temperature/Conductivity and pH.

D. Boydston, et al. (2015) [7] have given the design, development and deployment of sensor network of drifter nodes. The target domain is coastal water monitoring and study of Lagrangian water dynamics. The nodes were equipped with a camera, inertial measurement unit (IMU), GPS, Wi-Fi and a computing unit. Each unit is water resistant with buoyancy characteristics that enable it to float in a vertical position.

## **2.2. Water Quality Monitoring**

Yue and T. Ying, (2011) [8] have designed a WSN based system for water monitoring system and focused on measuring the oxygen content, turbidity and pH value of water. The system is powered via a solar cell. WSN nodes distributed randomly and a sink node at base station for collecting the water quality data. The main advantage of this system is low power consumption and flexibility in deployment.

W. Y. Chung, and J. H. Yoo (2015) [9] have designed WSN based field servers to sense the information about water quality parameters from wide areas such as; coastal areas, rivers and streams. They have used solar energy harvester to energize the field servers. For the reduction of communication traffic and adequate data transmission in the middle of base station and field servers, they have designed a data averaging practice.

B. O'Flynn, et al. (2007) [11] have worked on measuring water quality parameters and WSN based multi sensor system design and titled as Smart Coast; a new platform has been designed and implemented for the investigation of water parameters for water quality management and measurement. Sensing devices of Smart Coast system were temperature, pH, oxygen

content, conductivity, turbidity, and water level of water bodies.

D. S. Simbeye and S. F. Yang, (2014) [12] have designed real time wireless system for monitoring as well as controlling the various parameters of water. The parameters under monitoring and controlling were pH value, temperature, oxygen content, and water level. The sensed data transmitted via ZigBee transmitter to the base station. The Lab VIEW platform has been used for the analysis of outcomes.

## **2.3. Energy harvesting**

F. K. Shaikh, and S. Zeadally (2016) [15] have presented a comprehensive review on the taxonomy of renewable energy sources towards wireless sensor networks and focused two classes of energy harvesting sources i.e., ambient sources and external sources. RF, solar, thermal and flow (wind and hydro) are lies under the category of ambient sources and mechanical (vibration, pressure and strain-stress) and humanoid (bodily, physical and activity) falls under the external energy harvesting sources.

A. Dewan, et al. (2014) [16] have reviewed about the renewable energy sources for powering the environmental monitoring systems located at remote areas. Their proposed system is a best alternative to the traditional batteries. Researchers initially discussed about remote sensors and then the power requirements and working principle of renewable sources for remote sensors, renewable energy sources challenges and finally, the power management.

## **2.3. Harvesting Techniques**

J. J. E. Lopez, et al. (2018) [31] suggested that presently, batteries are generally used to power-up internet-of-things (IoT) devices. Though, use of batteries enforces significant restrictions to operation of system, because they require be recharging or interchanging after certain period of time. Depending on proposed application, this can be a very

challenging process or even not possible choice. To overcome these restrictions, designers are recurring to energy harvesting (EH) systems to extend battery life and allow independent operation of IoT end-nodes.

In current years, several power management units (PMUs) that harvest energy from single transducers have been introduced. The most common selected sources of energy are light, thermal gradients, mechanical vibrations and radio frequency (RF) signals. Though, it has been observed that due to ambient variations, single harvesting sources can exhibit long periods of energy shortage, which reduces their overall dependability. As main goal of a PMU is to provide a constant supply to its load, even when operating from irregular energy sources; design of an autonomous system that relies on single harvesting source can be quite challenging. Collecting energy from several sources turns to be more reliable method for powering IoT end-nodes. This is especially case if complementary / heterogeneous transducers are considered as harvesting devices.

#### **2.4. Data Transformation**

S. O. Olatinwo, and T. H. Joubert, (2018) [28] suggested that Wireless sensor network (WSN) technology is promising inexpensive method which involves deployment of different sensor nodes measuring water quality at a desired water-processing station. Monitoring parameters might normally include inorganic and organic contaminants such as pH detection, dissolved metal ion detection, and bacterial load detection. The data collected by water-quality sensor nodes concerning quality of water at water processing station is transmitted to different data centers. The data centers investigate water quality data, based on analysis and essential conclusions are made. WSN is not only valuable tool employed in water quality monitoring but also

for water leakage monitoring, traffic monitoring, to collect, process, and distribute environmental data to several centers.

B. Ali, et al. (2018) [30] have proposed a reliable and energy-efficient routing (R-ERP2R) protocol for UWSNs water quality monitoring. This protocol balances energy consumption and decreases delay by utilizing physical distance at time of data packet transmission. Every sensor node calculates estimated transmission count for each of its neighbor to find link quality for reliable transmission of data packets. A lowest depth neighbor in range with high residual energy and good link quality is selected as forwarder. R-ERP2R forwards only one copy of a data packet to increase network lifetime. However, if a data Packet reaches void region, sensor node drops it which results in retransmissions.

#### **2.5. WSN deployment for water quality monitoring**

A. Goswami, and M. Kumar. (2017) [26] has presented concise review of protocols in WSN for energy harvesting. In Water Quality Monitoring: WSNs can be deployed under water or at surface to detect quality of water and create a more perfect map of Water status from all of above-mentioned sources. WSN reduces manual retrieval of data and inspires his team to help detecting places which are facing difficulties to access right quality of water.

M. Pule, et al. (2017) [27] viewed that Water quality monitoring has thus become important to supply of clean and safe water. Wireless sensor networks (WSN) have since been considered a promising alternate to complement conventional monitoring processes. These networks are relatively cheap and permit measurements to be taken remotely, in real-time and with negligible human interference.

TABLE I. Comparative analysis between proposed framework and existing frameworks.

Sr. #	Compared parameters	Existing frameworks							
		[8]	[9]	[10]	[11]	[12]	[29]	[31]	This work
1.	Water quality sensors	✓	✓	✓	✓	✓	✓	✗	✓
2.	Energy harvesting techniques	✓	✓	✓	✗	✗	✗	✓	✓
3.	Energy management	✓	✓	✗	✓	✗	✗	✓	✓
4.	Energy storage	✓	✓	✓	✓	✗	✓	✓	✓
5.	IoT features	✗	✗	✓	✗	✓	✓	✓	✓
6.	GPS Module	✗	✗	✓	✗	✗	✗	✗	✓
7.	GUI tool	✓	✓	✓	✓	✗	✗	✗	✓
8.	Database / Memory	✗	✓	✓	✓	✓	✓	✗	✓
9.	End user application	✗	✗	✓	✗	✓	✓	✗	✓

### 3. Problem Statement

After the illustration of extensive literature review, it is concluded that the designed platforms and systems have not capability of continuous monitoring. Besides this, there is no any sustainable energy mechanism for FSNs to monitor the water quality data. FSNs are not suitable for continuous monitoring of water reservoirs. They have limited life to measure the water parameters. To overcome these issues, we have proposed to design a novel system in which there is no issue regarding power for operating the FSNs everlasting. The nodes should have capability of continuous monitoring of water bodies. Nodes should fetch the data autonomously.

The considerable problems of FSNs are energy management, reliable data dissemination, congestion detection, deployment strategy, security and management of a sensor network itself. The main problem is to simulate the network protocols in parallel with the environmental parameters, energy harvester, circuits and storage blocks. Also, it is an utmost issue for a node deployment strategy to meet the

design objectives. Generally, the deployment of sensor nodes produces congestion in sensor networks. Lifetime evaluation of sensor networks is a challenging task, for which, these parameters require much consideration for the robustness:

- Energy harvesting and storage block
- Node scheduling
- Reliability and congestion control in the network
- Optimal node deployment
- Ad-hoc nature

### 4. Research Questions

Following are research questions of proposed work.

- 1) Is this course is limited to certain domain of water quality monitoring i.e. ocean, sea, streams, lakes, irrigation, drinking water, etc.?
- 2) Are we familiar about the parameters either natural/manmade that will affect the values of our concerned measuring parameters for water quality data?

- 3) The proposed system is strictly limited by means of computation, storage and communication. How can we handle and design such low complexity power management solutions for those hardware constraints?
- 4) Does the chosen energy harvesting subsystem model fulfil the needs of network lifetime of sensor node objectives for the desired applicative scenarios?
- 5) How can we organize duty cycle strategies to control congestion and ensure the reliability of data transmission?
- 6) What are the key factors that need to be considered for optimal placement of floating nodes at different deployment cases?

## 5. Generic Framework

The proposed generic framework consists of four different blocks as shown in Fig. 1. We must highlight these four blocks. (1) Application: FSN based [5-7] continuous monitoring of water parameters [8-14, 29] that will help for improving the water quality, (2) Energy harvesting [15-19]: provision of adequate energy for long life monitoring without replacing any battery, (3) Data transform [22, 23]: congestion control and reliable data transfer at remote station (4) Deployment [24, 25]: random deployment of floating nodes. The purpose of each block of the proposed framework is explained here.

### 5.1. Application

As we develop FSN based system for continuous water quality monitoring. Once the water quality parameters have been detected, then it becomes easier and simpler to improve its quality by incorporating different chemical procedures. Researchers may use this framework according to their desired application scenario like fish farms, habitat monitoring, bridge monitoring etc.

### 5.2. Energy harvesting

This block consists of two sub-blocks. First one is energy harvesters such as solar, wind, water flow, etc. For our proposed system, we are supposed to use solar and wind harvester as a renewable energy sources to fulfil the power needs of the proposed system devices like, sensing devices, microcontroller, communication devices, and so on. Second one is harvesting aware power Management. This block is concerned to handle, manage and storage of the harvested energy in super capacitor and secondary batteries and for providing useful energy as per their requirements.

### 5.3. Data transform

This block has two types of contributions the reliability module and congestion control. The purpose of reliability module is to transfer data reliably in terms of maximizing the data delivery ratio and minimizing the miss packets ratio. The contribution of congestion control block is to handle the packet transmissions without packet collisions, by incorporating different algorithms to minimize or avoid the number of re-transmissions in case of miss or dropped packet scenario. By which, packets collisions are sufficiently reduced.

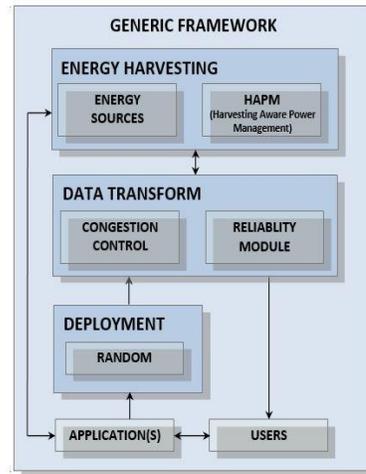


Fig. 1. Generic framework of proposed system

**5.4. Deployment**

The deployment of nodes can either be randomly or deterministically. It depends upon the requirement of the network or application designers. Well, we use fixed deployment or anchored deployment strategy and random deployment strategy for the proposed system. The pictorial representation of deployment strategies is given in Methodology section. The deployment strategies have a significant impact of the network metrics such as network topology, routing protocols, reliable data transfer and so on. So, for improving the network performance, we must adopt a suitable deployment strategy.

**6. System Architecture**

Fig. 2 depicts the energy process architecture: from harvesting to utilization and partitioned into three main sections as discussed below.

**6.1. Energy harvesting sources: solar and wind**

The energy harvesting sources consists of two distinct types of energy harvesters such as, solar and wind to fulfil the energy requirements. For improving the mission-life of FSNs, renewable energy sources will be provided accordingly. Energy harvester are used to facilitate the proposed system to avoid

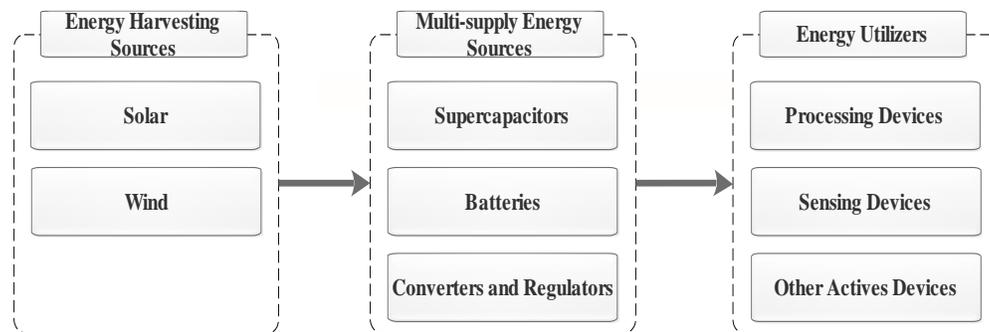
the abruptness and battery replacement in the measurement of water quality data. The harvested energy obtained from the harvesters is provided to different active electronic devices.

**6.2. Energy-supply energy sources: super capacitors, batteries, converters and regulators**

To provide desired voltage ranges as per specifications of devices, this practice is done via power management scheme by incorporating different energy converters and regulators such as MPPT. The maximum power point tracking (MPPT) [17] provides the maximum output efficiency by maintaining the duty cycles. Super capacitors and secondary batteries are here for storing the energy gained from energy harvesters [17-19].

**6.3. Energy utilizers: processing devices, sensing devices and actives devices**

This section is comprised of various active devices, which utilizes the energy viz. processing devices, sensing devices and their drive circuitries, communication devices, etc. According to datasheets, every device has different current and voltage ratings. So, for the provision of adequate energy as per device requirement is accomplished by energy converters and regulators as discussed as earlier.



**Fig. 2.** Energy process architecture: from harvesting to utilization

Fig. 3 describes the black box general proposed system, where different modules of the node are mentioned. The proposed

architecture of FSN node consists of sensing devices, microcontroller unit, ZigBee transceiver, GPS module and power management blocks (power source and energy buffers). Sensor node is composed of sensing devices along with drive circuitry and converts to enable the sensors for the communication with microcontroller unit. The fetched data is transmitted by ZigBee transceiver at the base station. GPS is used to track the position and location status of the nodes. To provide desired voltage ranges according to the specifications of devices; this practice is done via converters, MPPT controller and power management scheme.

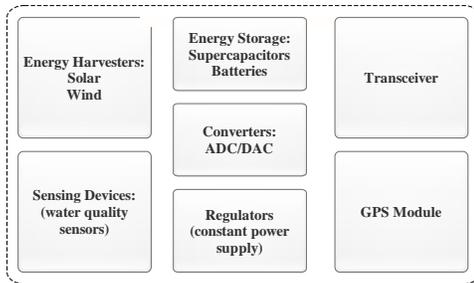


Fig. 3. FSN node general architecture

This FSN node has three different challenges, which are: shaping a new platform for real time monitoring efficiently, development of software algorithms to incorporate hardware for autonomous monitoring and data transferring, incorporation of various modules of the node with the microcontroller unit to achieve desire objectives by making it fully quantifiable.

## 7. Reseach Methodology

The deployment scenario of floating nodes is depicted in Fig. 4, in which fixed or anchored deployment is depicted in Fig. 4a and random deployment is depicted in Fig.. 4b for designing any novel platform for performing some dedicated tasks. The datasheet for each part of the system must be observed before selecting for proposed system. We are aimed to design a novel hardware platform for real time continuous monitoring of water quality parameters. There

are various software platforms for the programing of the nodes. For the visualization of measured data, a GUI tool will be designed and database for record keeping. The proposed system is comprised of a sink node at base station and various number of sensor nodes deployed in water bodies. ZigBee transceiver is responsible for transferring the data to base station. The GPS module will be equipped with sensor nodes for tracking the position and location status. The nodes will be deployed randomly into water reservoirs for real time monitoring and continuously.

Our proposed methodology is based on following five steps:

### 7.1. Data collection

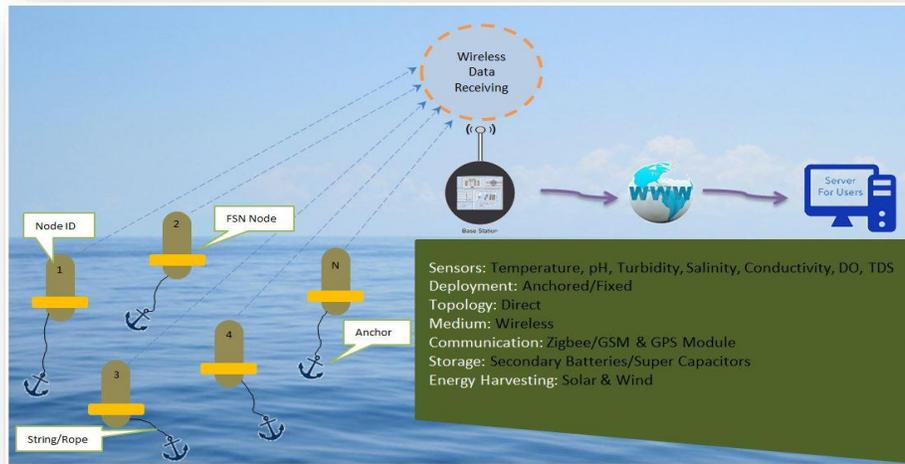
In the first step of proposed system of the network various floating nodes will be deployed in the water (lake or river). Each node will be equipped with different sensors which are temperature, conductivity, turbidity, salinity, pH, dissolved oxygen and total dissolved solids. These nodes will be designed and programmed to collect water parameters individually and that sensed data after collection is stored in the microcontroller accordingly.

### 7.2. Data transmission

In the second step, the data will be transmitted wireless, and ZigBee transceiver module will be used at transmission and reception sides. All nodes will send the collected data to central monitoring center or base station using direct topology. The position of each node is also accorded at base station via GPS module for updating the status of locations.

### 7.3. Base station

In the third step, base station will collect the data from all floating nodes using ZigBee transceiver, where visualization of data via GUI tool will be carried out. After receiving data from each node, the data is sent to the Ethernet shield which is used as a gateway to transfer the data over web for end user.



(a) Anchored/Fixed Deployment



(b) Random Deployment

Fig. 4. Proposed Research Methodology

#### 7.4. www

In the fourth step the data will be sent over the web, by which the data is accessed by the server for further processing. Also, end user can access the data via internet sources.

#### 7.5. Server

In the last step the data will be received at server via internet and stored in the database for further processing, initially the data will be differentiated using the node IDs to process the data of each node separately, after

identification the data is collected by web for final step, over here three tasks will be executed which are given below.

- *Status check:* this is used to check the status of each node whether it is up or down, sometimes the transmission is interrupted because of higher attenuation causing object in between or temporary failure of link etc.
- *Graphs generation:* here, the data of each sensor is used to generate a continuous line graphs to show the instantaneous values and status of the water relating to the sensor.

*Notifications/Alerts:* Notifications and alerts will be used to indicate if any of the water parameter is not in the desired state and has crossed threshold, it will be notified by triggering warning to use precautions to make the parameters back to normal

## 8. Expected Outcomes

The proposed energy harvesting based FSN system is beneficial for both public and private sectors. The proposed novel system tackles two most key issues; energy and water that are being faced in our country Pakistan very dramatically. Furthermore, we have evaporated some other pivotal role of our system under following sections.

### 8.1. Industry

There are various water-purifiers, food factories, raw material (cement, etc.) factories and industries are available around the world, for these procedures, safe water is an important ingredient. For the provision of safe and hygienic water, water quality monitoring system will play pivotal role for the treatment of water. This proposed system is fit for this requirement.

### 8.2. Academia

Academia is the main part of research in this world and day by day it is promoted exhaustively by fetching and executing the

ideas that are developed by the researchers. By working on this project, we can develop the linkages of useful research among the researchers and can produce different creative domains of research for further enhancement and improvement in the water quality monitoring domain.

### 8.3. Community

As water is the fundamental need of human beings and other living organisms. According to medical research, a common human being is using average of 10 liters of water every day for their survival on this Earth and obviously being a sensible human, we cannot tolerate the quality factor of this basic need. Hence, by monitoring the parameters of water we can improve the quality of water at its best, so that, every living organism can access or avail good quality water.

### 8.4. Government

After successful compilation of the statistics of water quality data, government can invest to develop some water purification plants to provide the best quality water to industries, communities, and other sectors of environment around us.

## 9. Conclusion

The proposed work has provided the details regarding the experience picked up in the context of development of a system of floating sensor network for collecting water quality data by introducing a novel framework. The proposed framework comprised of four domains; 1) application (e.g., water quality monitoring system), 2) energy harvesting, 3) data transform and 4) deployment. Meanwhile, each block also classified into sub-classes. We have addressed to propose a system based on FSN to monitor the water quality data continuously. For which we have introduced a novel architecture for FSN node platform.

The FSN Node is equipped with in-situ sensors; The FSN collect the data and transmit it at the base station via ZigBee transceiver module. Where measured data is displayed on

a display tool for users and a database for record keeping. As well as, this data is transmitted at remote station for end users via internet.

For the accomplishment of continuing monitoring, the alternating energy sources such as solar wind is provided to FSNs. The data transform module is addressed for the improvement of data reliability of the proposed system and avoid the congestion created during the data transmission. The proposed methodology of FSNs node deployment are addressed to be fixed deployment and random deployment at different outdoor sites for continuous monitoring. Finally, we have highlighted the end users and beneficiaries for which this proposed system is useful for the water treatment procedures.

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#### REFERENCES

- [1] R. M. White, "A sensor classification scheme", *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 34, no. 2, pp. 124–126, 1987.
- [2] I. F. Akyildiz, W. Su, Y. Sankarasubramanian, and E. Cayirci, "A survey on sensor networks," *IEEE Communication Magazine*, vol. 42, no. 5, pp. 102–114, 2002.
- [3] I. F. Akyildiz, W. Su, Y. Sankarasubramanian, and E. Cayirci, "Wireless sensor networks: A survey", *Computer Networks*, vol. 38, no. 4, pp. 393–422, 2002.
- [4] M. F. Othman and K. Shazali, "Wireless sensor network applications: A study in environment monitoring system", *International Symposium on Robotics and Intelligent Sensors*, vol. 41, pp. 1204 – 1210, 2012.
- [5] A. Tinka, M. Rafiee, and A. M. Bayen, "Floating sensor networks for river studies". *IEEE Systems Journal*, vol. 7, no. 1, pp. 36–49, 2013.
- [6] J. Beard, K. Weekly, C. Oroza, A. Tinka and A. M. Bayen, "Mobile phone based drifting lagrangian flow sensors," *IEEE 3rd International Conference on Networked Embedded Systems for Every Application (NESEA)*, pp. 1-7, 2012.
- [7] D. Boydston, M. Farich, J. McCarthy, S. Rubinson, Z. Smith and I. Rekleitis, "Drifter Sensor Network for Environmental Monitoring", *Computer and Robot Vision (CRV), 12th Conference on, Halifax, NS*, pp. 16-22, 2015.
- [8] R. Yue and T. Ying, "A novel water quality monitoring system based on solar power supply & wireless sensor network", *International Conference of Environmental Science and Engineering*, vol. 12, Part A, pp. 265 – 272, 2012.
- [9] W.Y. Chung, and J.H. Yoo, "Remote water quality monitoring in wide area", *Sensors and Actuators B: Chemical*, vol 217, pp:51-57. 2015.
- [10] A. Faustine, A. Mvuma, H. Mongi, M. Gabriel, A. Tenge, and S. Kucel, "Wireless Sensor Networks for Water Quality Monitoring and Control within Lake Victoria Basin: Prototype Development". *Wireless Sensor Network*, vol 6, pp: 281-290, 2014.
- [11] B. O'Flyrm, R. Martinez, John Cleary, C. Slater, F. Regan, D. Diamond, and Heather Murphy. "SmartCoast: a wireless sensor network for water quality monitoring." In *Local Computer Networks, 2007. LCN 2007. 32nd IEEE Conference on*, pp. 815-816. IEEE, 2007.
- [12] D. S. Simbeye and S. F. Yang, "Water quality monitoring and control for aquaculture based on wireless sensor networks", *Journal of Networks*, vol. 9, no. 4, 2014.
- [13] J. Wang, X. Ren, Y. Shen, and S.Y. Liu, "A remote wireless sensor networks for water quality monitoring", *Innovative Computing Communication, International Conference on and Information Technology Ocean Engineering*, pp. 7–12, 2010.
- [14] P. Jiang, H. Xia, Z. He, and Z. Wang, "Design of a water environment monitoring system based on wireless sensor networks", vol. 9, no. 8, p. 6411, 2009.

- [15] F.K. Shaikh, and S. Zeadally, "Energy harvesting in wireless sensor networks: A comprehensive review". *Renewable and Sustainable Energy Reviews*, vol 55, pp: 1041-1054, 2016.
- [16] A. Dewan, S. U. Ay, M. N. Karim, H. Beyenal, "Alternative power sources for remote sensors: A review", *Journal of Power Sources*, Volume 245, Pages 129-143, ISSN 0378-7753, 2014.
- [17] F. Akhtar and M. H. Rehmani, "Energy replenishment using renewable and traditional energy resources for sustainable wireless sensor networks: A review", *Renewable and Sustainable Energy Reviews*, vol. 45, pp. 769 – 784, 2015.
- [18] P. D. Lund, J. Lindgren, J. Mikkola, and J. Salpakari, "Review of energy system flexibility measures to enable high levels of variable renewable electricity", *Renewable and Sustainable Energy Reviews*, vol. 45, pp. 785 – 807, 2015.
- [19] B. S. Srujana, Neha, P. Mathews, and V. Harigovindan, "Multi-source energy harvesting system for underwater wireless sensor networks", *International Conference on Information and Communication Technologies, ICICT*, vol. 46, pp. 1041–1048, 2015.
- [20] P. Nintanavongsa, "A Survey on RF Energy Harvesting: Circuits and Protocols", *Energy Procedia*, Volume 56, Pages 414-422, 2014.
- [21] S. Peng, T. Wang, and C. Low, "Energy neutral clustering for energy harvesting wireless sensors networks", *Ad Hoc Networks*, vol. 28, pp. 1 – 16, 2015.
- [22] P. Yadav, and U.K. Verma, "Wireless Sensor Network (WSN): A Reliable Data Transfer Using Spaced Hop by Hop Transport", *International Journal of Engineering Science Invention*, Volume 2 Issue 5, PP.26-30, 2013.
- [23] F. Yunus, N. S. N. Ismail, S. H. S. Ariffin, A. A. Shahidan, N. Fisal and S. K. Syed-Yusof, "Proposed transport protocol for reliable data transfer in wireless sensor network (WSN)", *4th International Conference on Modeling, Simulation and Applied Optimization (ICMSAO)*, Kuala Lumpur, pp. 1-7, 2011.
- [24] A. Rahman, A.R. Alharby, H. Hasbullah, and K. Almuzaini, "Corona based deployment strategies in wireless sensor network: A survey", *Journal of Network and Computer Applications*, Volume 64, pp: 176-193, 2016.
- [25] G.S. Rao and V. Vallikumari, "A Beneficial Analysis of Node Deployment Schemes for Wireless Sensor Networks", *International Journal of Advanced Smart Sensor Network Systems (IJASSN)*, Vol 2, No.2, 2012.
- [26] A., Goswami, M., Kumar, "A review on energy harvesting in wireless sensor Networks" *International Journal of Innovative Research in Science, Engineering and Technology*, ISSN(Online) : 2319-8753 ISSN (Print) : 2347-6710, Vol. 6, Issue 4, 2017.
- [27] M. Pule, A., Yahya and J. Chuma, "Wireless sensor networks: A survey on monitoring water quality", *Journal of Applied Research and Technology* 15 pp: 562–570 2017.
- [28] S. O. Olatinwo and T. H. Joubert, "Optimizing the Energy and Throughput of a Water-Quality Monitoring System" *Sensors* 18, 1198, 2018.
- [29] L. Parra, S. Sendra, L. Garcia, and J. Lloret, "Design and Deployment of Low-Cost Sensors for Monitoring the Water Quality and Fish Behavior in Aquaculture Tanks during the Feeding Process", *Sensors* 18, 750, 2018.
- [30] B. Ali, A. Sher, N. Javed, K. Aurangzeb, and S.I. Haider, "Retransmission Avoidance for Reliable Data Delivery in Underwater WSNs", *Sensors*, 18(1), p.149, 2018.
- [31] J. J. E. Lopez, A. Abuellil, Z. Zeng, and S. E. Sánchez, "Multiple Input Energy Harvesting Systems for Autonomous IoT End-Nodes" *Journal of Low Power Electronics and Applications*, 8(1), 6., 2018.