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Design and Performance Analysis of Rural Aquaculture Ponds using IoT

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Abstract*: Rural aquaculture is mostly based on open pond system. People in rural areas depend on aquaculture not only for food but also for livelihood. These are unmanaged fish ponds and deprived of any technological touches. To increase the livelihood, establishment of managed ponds and use of low cost IoT technology for monitoring fishponds is an important issue. By monitoring water parameters like PH, temperature, Turbidity fish growth can be increased. In this paper we have proposed a multiple fish pond design controlled by single center and wire and wireless mode of data collection. The proposed model is simulated using NetSim to generate network performance matrices. To achieve a prolonged battery life, concept of energy harvesting at sensor node level is introduced in the simulation study.

***Index Terms*: Aquaculture, IoT, Zigbee, Sensors, Fishpond**

I. INTRODUCTION

Aquaculture is an important source of food and livelihood for millions of people around the world and fish consumption will considerably increase by 2050 [1]. The inclusion of fish in diet provides more nutrition rather than the cereal-based diets for all the age group people. For economically backward rural areas aquaculture proved to be an excellent opportunity for employment and income generation.

Fish farming in ponds is an artificial man made eco-system. Hence it is important to maintain the balance in the eco-system. Fish depends on water to live, eat and perform the regular bodily activity. Hence, water quality plays an important role to determine growth of fish in freshwater aquaculture. Water temperature, Dissolved oxygen, PH, Turbidity and Conductivity are the basic water parameter the determines stability of a fish pond [2]. In recent years with the development of Internet of Things (IoT) systems are automated easily. By deploying low cost sensor devices it is easy to collect the water parameters in fish farming. Also the farmer has to understand the process of testing and interpretation of result to take necessary action. This idea of automation creates some problem to the farmer:-1) manually collecting Individual water parameter from different part of the pond is time consuming. 2) Remotely accessing the sensor devices for data collection without presence of any human being locally. 3) Randomly deploying the sensor devices with fish ponds without any size and location management of fish Ponds. Out of the three problems urban and professional fish farmers has the ability to access expert resources to solve them. But rural farmers created their unmanaged fish ponds.

Fig 1. (a) Rural unmanaged fish pond; (b) managed fish pond

Scope of Rural aquaculture: Rural aquaculture is based on the farming of aquatic organisms by small scale. This meant for house hold or communities by use of low cost technology based on the available resources. In this level of farming the fish production is less resulting in low family income. But by converting their fish ponds to managed one and by implementing low cost IoT based aquaculture, not only increased their livelihoods but also adequate amount of fish for community.

The goal of our paper is to represent the problem area of rural aquaculture using unmanaged fish ponds. Deployment of the IoT technology for simplifying and monitoring fish ponds. Design the position of fish ponds with respect to the sensor nodes and simulate it using NetSim for different performance factors of the proposed design.

Rest of the papers is organized as following. Section II represents some related work regarding aquaculture using IoT and it's prospective. Section III proposed fish pond design with sensors deployed on it and using IoT data is collected remotely at server. Simulation setup is done in section IV. In section V the performance of the proposed design is evaluated and result analysis is done. The conclusion of the paper is given in section VI.

II. RELATED WORK

This section describes the related work of the rural aquaculture at village ponds and water bodies' also technological aspect for water quality management. Rural culture of aquaculture based on open pond system. People mostly use unmanaged water bodies for fish farming.

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Also fish farming is found to be major source of livelihood and food. In paper [3] authors made a survey on different method followed for rural fish farming in Indian states and their statistics. They also identified how farmers are facing problem due to distance location of fish ponds from their place of living. And they left as a open problem to solve using some technology implementation. The small scale aquaculture for livelihoods in rural areas of Nepal is presented in [4]. It illustrates the opportunities and challenges in open pond based fish farming.

A review report on present status of fresh water aquaculture in India is presented in [5]. Here the author focused on the increasing demand of the fish requirement. The social, cultural and technological constraints for expansion of aquaculture along with climate change to meet the demand of fish are the major challenges.

With the advancement of IoT and sensor technology the above challenges can be solved on the context basis. In paper [6] authors implemented a wireless sensor based architecture for collecting water parameters by positioning it at the pond. They implemented the Zigbee based protocol standard for communication to the local server. A low-cost WSN for aquaculture monitoring has been proposed in [7]. Here authors analyzed the water parameters, tank state and fish behavior during the feeding process. An arduino based model has been designed for sensor data collection. An IoT based platform for remote water quality monitoring is capable of collecting sensors data from aquaculture ponds and communicate it to the remote servers. Farmers can make important decisions for improving the quality and quantity of the fish production [8].

Real-time fish pond monitoring and automation is proposed in [9]. Here authors integrated water pump with fishpond sensor architecture to fill fresh water under emergency situation. They regulate the PH and oxygen level, as they are the vital parameter for fish development and accordingly decision is taken for pump on or off. Authors in [10], have proposed an automated IoT system for fish farming where they monitor the water temperature, pH and water level, using Wi-Fi remote connection and this could be a problem for sites which placed far from internet connection areas.

All the available literature focused on IoT implementation for a single fish pond system and water quality data collection; hence in our paper we have addressed the following issues:

- ✓ Design issue of a multiple fish pond system with multiple sensors in each and single control system.
- ✓ Network related parameters and performance issues due to long wired or wireless connections.
- ✓ Energy related issues for long time operation of battery operated sensor nodes.

The multi pond system is simulated for generate the performance matrices and analyzed.

III. DESIGN OF FISH POND

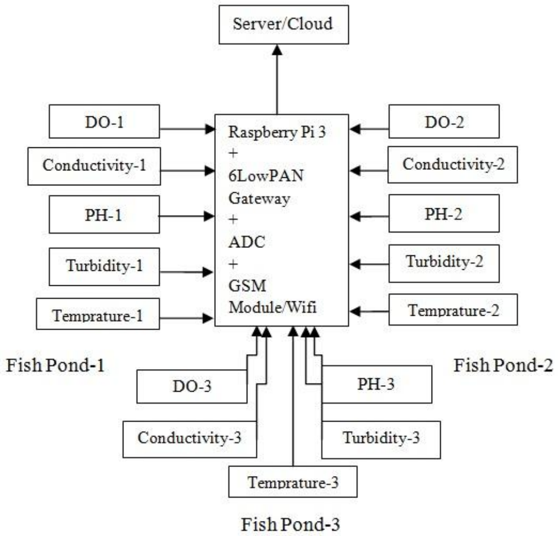

Fig. 2. Proposed deign for fish pond

This section represents a design of multiple fish ponds present nearby each other and IoT network set up for collection of water parameters. In our design we consider three fish ponds present in different distance from each other equipped with five sensors in each pond. The sensors are: Dissolve Oxygen Sensors, Temp. Sensors, Turbidity Sensor, Conductivity Sensors, PH Sensors. Sensors are connected with each other in ad-hoc manner forming a Zigbee network. A 6LowPAN gateway is used to connect this Zigbee network with outer network of IoT (Raspberry Pi). We have placed one wired and one wireless server for collection of water parameter date and its analysis. A GSM module / Wifi is used to issue SMS and e-mail alert. Also one router and one access point is used for data transmission in wireless mode.

IV. SIMULATION SETUP

In this section the proposed design is simulated using NetSim V11.1. We have used IoT components for performing the simulation. To study the performance of the proposed model we establish a communication path between sensor nodes and serving station as shown in figure 2.

From fish pond 1:
Node1→node18 (wired serving station)
Node3→node20 (wireless serving station)
From fish pond 2:
Node9→node18 (wired serving station)
Node7→node20 (wireless serving station)
From fish pond 3:
Node13→node18 (wired serving station)
Node13→node20 (wireless serving station)
To study the performance path loss we have setup a communication path from a single node to both the wired and wireless server.
Node 4→node18 (wired serving station)
Node 4→node20 (wireless serving station)

By changing the property of every component the corresponding performance matrices are generated and studied.

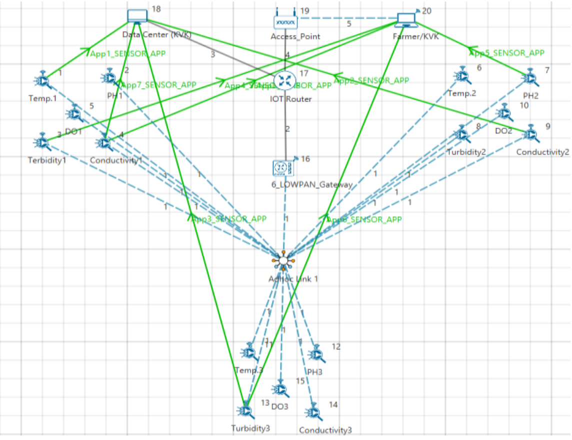

Fig 3. Simulation set up for proposed design of fish pond

Every path is associated with property of path loss and no loss. The 6LowPAN gate way is associated with the options of using AODV or RPL routing protocol. Each of the sensor nodes has a capacity to harvest energy for long battery life. The sensor nodes have the property to assign energy harvest on or off. For different performance factors the corresponding property is changed and the whole model is simulated. The result is recorded as data table and graphs.

V. RESULT AND ANLYSIS

In this section the following performance matrices for fish pond aquaculture is measured from simulated environment and presented as follows:

1) Energy Harvesting:

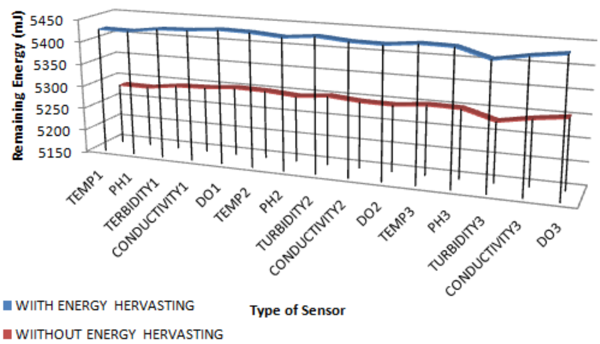

Fig 4. Energy harvesting graph for different sensors

This performance factor is obtain simulated by keeping energy harvesting option at the level of sensor nodes ON/OFF to see how much energy left out after the simulation is over in each case. The remaining energy for energy harvesting and without energy harvesting is represented in Fig.4 and data is given in table 1 and table 2. It can be seen that for every sensor the energy harvesting mode shows higher remaining energy level. Hence, for the fish pond design by considering sensors with energy harvesting option to generated energy from radio frequency wave/solar system is beneficial for farmers to achieve a prolonged battery life.

2) AODV Vs RPL:

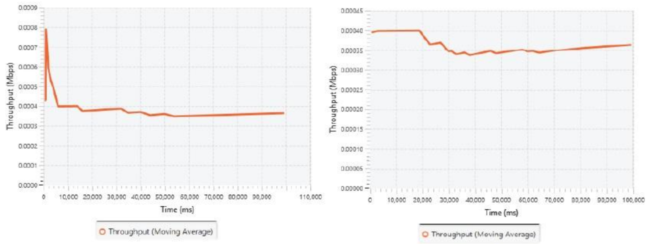

Fig 5. (a) AODV sensors (b) RPL

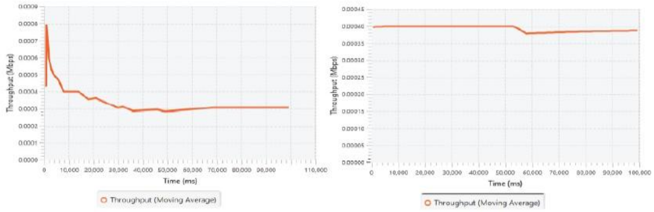

Fig 5. (c) AODV sensors (d) RPL

By setting the routing protocol to AODV and RPL type the system performance in terms of throughput of each application is recorded. Fig. 5 (a) and (b) represents throughput of the data transmission from node 4 to 18 (wireless station) and Fig. 5 (c) and (d) from node 4 to 20 (wire station) for AODV and RPL respectively. It can be observed that AODV initially produce a better throughput for a small time after that it drops to 0.0003 to 0.0004. In comparison to this RPL throughput starts with 0.00035 and varies till 0.00040. This is applicable to all four graphs. Hence, it can be conclude that RPL gives better throughput that AODV.

3) Path loss

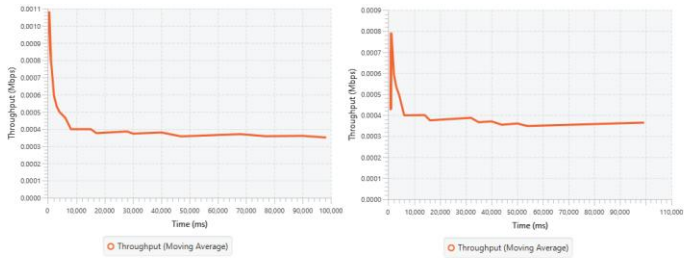

Fig 6. (a) No path Loss (b) path Loss

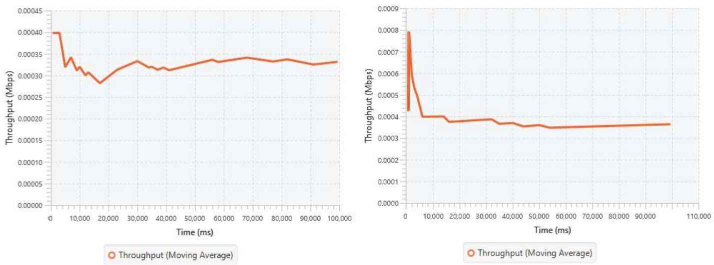

Fig 6. (c) No path Loss (d) path Loss

The throughput of the fish pond network with AODV routing when there is path loss/no loss in communication network is shown in Fig. 6(a), (b), (c), (d). It can be observed that in all cases either wireless station destination or wire station destination, a no path loss system shows higher throughput and performs better. Hence, while designing the fish pond network the possible type of path loss must be evaluated.

VI. CONCLUSION

In this paper we have presented an IoT based multiple fish pond design controlled by a single source to analyze the water quality parameters. The chances of path loss during data transmission form one node to another are performed by setting the node properties and hence the performance matrices in terms of throughput are calculated. Routing algorithm like AODV and RPL is compared for throughput of the application. The concept of energy harvesting is implemented at node level to increase battery life and the results for battery model in given in appendix. The results are presented in the form of graphs and tables.

APPENDIX

Table 1.Battery Model (With energy harvesting)

Device Name	Initial energy(mJ)	Consumed energy(mJ)	Remaining Energy(mJ)
TEMP.1	6480.000000	1195.173991	5427.406940
PH1	6480.000000	1195.899288	5426.697172
TERBIDITY1	6480.000000	1186.897258	5435.699202
CONDUCTIVITY1	6480.000000	1184.643931	5437.952529
DO1	6480.000000	1179.177052	5443.419408
TEMP.2	6480.000000	1180.628456	5441.968005
PH2	6480.000000	1185.914737	5436.681724
TURBIDITY2	6480.000000	1179.291754	5443.304707
CONDUCTIVITY2	6480.000000	1185.217069	5437.379391
DO2	6480.000000	1186.269194	5436.357774
TEMP.3	6480.000000	1179.270220	5443.326241
PH3	6480.000000	1180.583286	5442.013175
TURBIDITY3	6480.000000	1200.727077	5421.884041
CONDUCTIVITY3	6480.000000	1188.325643	5434.293077
DO3	6480.000000	1179.201137	5443.395323

Table 2. Battery Model (Without energy harvesting)

Device Name	Initial energy(mJ)	Consumed energy(mJ)	Remaining Energy(mJ)
TEMP.1	6480.000000	1195.173991	5284.826009
PH1	6480.000000	1195.899288	5284.100712
TERBIDITY1	6480.000000	1186.897258	5293.102742
CONDUCTIVITY1	6480.000000	1184.643931	5295.356069
DO1	6480.000000	1179.177052	5300.822948
TEMP.2	6480.000000	1180.628456	5299.371544
PH2	6480.000000	1185.914737	5294.085263
TURBIDITY2	6480.000000	1179.291754	5300.708246
CONDUCTIVITY2	6480.000000	1185.217069	5294.782931
DO2	6480.000000	1186.269194	5293.730806
TEMP.3	6480.000000	1179.270220	5300.729780
PH3	6480.000000	1180.583286	5299.416714
TURBIDITY3	6480.000000	1200.727077	5279.272923
CONDUCTIVITY3	6480.000000	1188.325643	5291.674357
DO3	6480.000000	1179.201137	5300.798863

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