Wireless Acquisition for Vigilant Earthquake in the Sea (WAVES)

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ABSTRACT

Tsunami is a wave, or series of waves in a waves train, generated by the sudden, vertical displacement of a column of water. This displacement can be due to seismic activity, explosive volcanism, landslide above or below water, an asteroid impact, or certain meteorological phenomena. As a coastal province, Batangas, Philippines is identified as a tsunami hazard province, specifically the municipalities of Nasugbu, Lian and Mabini. The recent earthquake swarms in April 2017 in different municipalities of Batangas which caused fear among coastline communities paved way for the researchers to develop a technology that can assist in detecting the occurrences of tsunami. This research aimed to develop a wireless sensor network for detecting the occurrence of tsunami. It aimed to make use of a ZigBee – based mesh network and GSM for data transmission. All electronic components were mounted on a fabricated buoy. The study made use of the innovative development approach. Evaluations of appropriate sensors, wireless transmission protocol and design standards were considered. After the conduct of thorough testing and evaluation of the system, the following conclusions were drawn. The sensor nodes composed of capacitive sensor arrays effectively detected possible presence of tsunami based on the sudden change of sea water level. The effective distances of the 1^{st}, 2^{nd} and 3^{rd}sensor arrays were 25m, 50m, 75m, and 100 m away from the seashore respectively, the combined ZigBee and GSM wireless protocol was effective in transmitting the status of the sensors which indicated the possible occurrences of tsunami. Overall, the system was found to be functional and efficient after series of actual in-situ testings.

Keywords: *wireless sensor networks, tsunami detection, ZigBee, GSM*

1. INTRODUCTION

Disasters are one of the common problems of the country, which are a burden since the cause massive loss of life and properties. One of the most destructive natural disasters is the tsunami, because as the waves strike the land it tends to clear or destroy everything on its path. A tsunami is a wave, or series of waves in a waves train, generated by the sudden, vertical displacement of a column of water. This displacement can be due to seismic activity, explosive volcanism, landslide above or below water, an asteroid impact, or certain meteorological phenomena [1]. Greatest damage is caused by the mass of water that may result to great smashing force and flash flood. Through this great smashing force caused by massive water, a tsunami destroys buildings, infrastructures and different properties, while flash floods can kill people by drowning.

According to Philippine Institute of Volcanology and Seismology (PHIVOLCS), a strong quake in Manila Trench could cause a 32-ft tsunami. A strong earthquake in the Manila Trench, an ocean trench west of the country that runs as deep as 5,400 meters, could trigger tsunamis up to 11 feet tall that can hit Metro Manila in a little more than an hour. The PHIVOLCS said that Metro Manila and western Luzon have more than just the West Valley Fault to worry about. He mentioned that if the Manila Trench shakes and causes a magnitude 8.2 earthquake, western Bataan can expect a wave up to 10 meters tall (around 32 feet) within 5 to 10 minutes. The tsunami could also hit Occidental Mindoro, Zambales, Batangas and Cavite within minutes. The same quake could send a tsunami through Manila Bay to hit Malabon, Navotas, Manila and Las Piñas, (Solidum). The effect would reach the NCR areas more than an hour with an estimate height of 11 feet.

Although it is impossible to predict when an earthquake will happen, a strong earthquake will likely be followed by a tsunami. Among the signs that residents of coastal areas should watch out for are unusual changes in sea level and a rumbling that precedes a tsunami [2].

There are natural signs of an approaching local tsunami such as shake - a felt earthquake, drop - unusual sea level change, sudden seawater retreat or rise, exposure of corals, underwater rocks and marine life and roar, rumbling sound of an approaching waves. [3].

The aforementioned problems prompted the researchers to conduct a study on the development of a tsunami detection system dubbed as wireless acquisition for vigilant earthquake in the sea or WAVES. The system could detect and monitor tsunami in the province of Batangas. The system has detection sensors, a ZigBee – based mesh wireless network, a data communication system using Global Mobile System (GSM), graphical user interface for viewing of analyzed data, and interpretation. The detection sensor is used to detect water rushes away from the shore which may signal an impending tsunami. The four sensors are connected to mesh network via ZigBee. The mesh topology allows the sensor nodes to reconfigure routing paths based on the new network structure. Information generated by the sensors is sent real-time by mesh network gateway and then sent to the Data Receiving Center by GSM communication.

With this study, it is hoped that Batangas Province would be greatly benefited by the WAVES since a big portion of this province lies along Batangas Bay, making prone to tsunami.

Objectives of the Study

This study attempted to develop a tsunami detection device dubbed as wireless acquisition for vigilant earthquake in the sea (WAVES). Specifically, this research sought attainment of the following: (1) To integrate a monitoring system that will detect tsunami with considerations on the dry and wet sensors and tsunami standards and protocol; (2) To configure ZigBee/ Mesh and GSM data network transfer; (3) To construct a buoy that can carry the solar panel, sensor and ZigBee module and withstand the high impact of sea waves; (4) To simulate and deploy the device based on the design requirements; and (5) To characterize the proposed design's functionality, performance and robustness relative to accuracy, effectiveness, efficiency, safety and speed.

2. MATERIALS AND METHODS

Research Design

This study used the developmental and experimental method of research. A descriptive approach was used for the evaluation of the device.

Pre-Design Stage

The pre-design stage was comprised of data gathering activities. The researchers collected and examined relevant information regarding tsunami, power generator, solar power, communication system, and sensors and their application, specifically in relation to the development of WAVES. The related studies and concepts used by previous researchers were likewise examined for other relevant inputs on the development tsunami detecting device.

Design Stage

This stage involved the conceptualization the overall design of the device including the components to be integrated to form WAVES. The data collected from the previous stage were used as reference to come up with the design. The researchers identified the specifications and technical qualifications of the components as well as methods required to perform the implementation of the design.

Methods of Fabrication and Assembly

Figures1 and 2 show physical setup of WAVES. To attain the desired output, the researchers followed these procedures: (1) *preparation of materials and equipment*. The availability and price of needed materials were checked. Tools and equipment for assembly were tested before purchasing them. The design consisted of detection sensors, a data communication system using GSM data communication modules, data visualization, interpretation, local tsunami emergency decision tools, mechanical component, solar panel, wires and other miscellaneous parts. (2) *Fabrication of the monitoring system*. The researchers fabricated the mechanical parts of the system specially the four buoys and three-meter pole for the ZigBee and GSM gateway. (3) *Installation of detector sensor and data communication system*. The researchers used a ZigBee wireless network and GSM data communication module to to transfer data into remote server. (4) *Installation of solar power system.* (5) *Assembly of the components*. Components were assembled construct the system. (6) Wiring and connection. The system wiring connections were properly connected according to the schematic diagram. Electrical safety was main consideration.

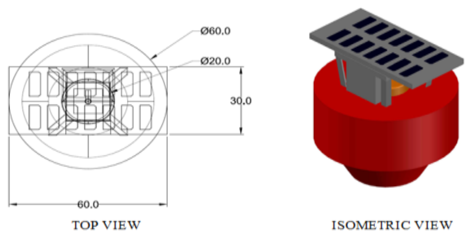

Figure 1. Design of WAVES Chasis

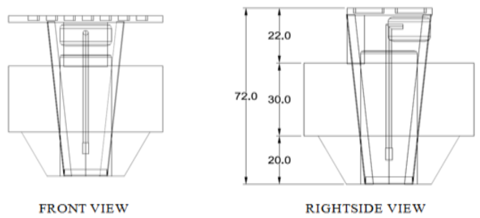

Figure 2. Dimensional Views of WAVES

Method of Data Collection and Transfer

The researchers used ZigBee/mesh wireless network for data collection from sensor.

GSM data connection was used by the researchers for transferring the collected data into remote area server. Figure 3.shows the block diagram of the flow of the wireless sensor network.

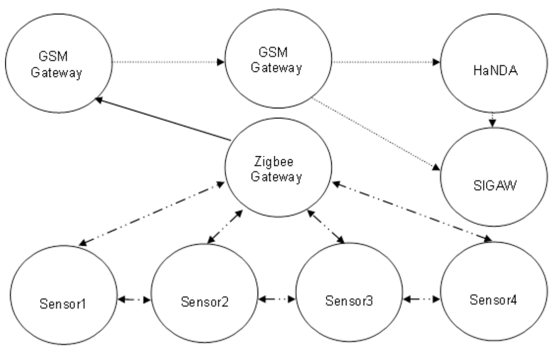

Figure 3. Flow Diagram

Legend:
Wired ——▶, Wireless ZigBee Mesh; –··–··–··–▶ and Wireless GSM ·························.

Method of Testing

The system was tested to know the prototype's capacity, accuracy, efficiency, speed, functionality and safety Figure 4 illustrates the experimental set-up of the study.

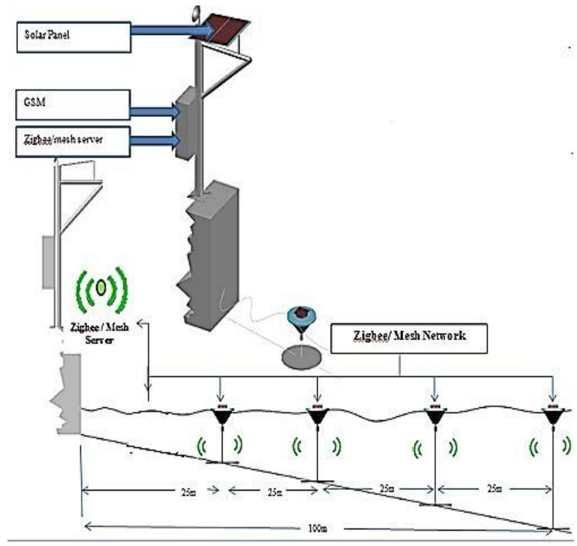

Figure 4. Experimental Set-up of the Study

Materials and Components

This stage includes the system components used, their features and their functions in WAVES sensor.

Capacitive Sensor

Capacitive proximity sensors can detect nonmetallic targets and lightweight or small objects that cannot be detected by mechanical limit switches. They provide a high switching rate for rapid response in object counting applications. They can detect liquid targets through nonmetallic barriers, like glass, plastic and among other [4].

This study's sensor is used to detect if the sea water rushes away from the seashore which is a sign of an impending tsunami. In the selection of sensor, the system requirements were given more importance to choose the most applicable sensor. The possible sensors were also evaluated using their specification sheets, their market availability and their cost.

Figure 5. Capacitive Sensor

Figure 5 shows the actual picture of the capacitive sensor module used by the researchers in the system. This was installed in the bottom center of the buoy.

ZigBee module

The ZigBee module was used as communication medium between the four sensors and Gateway. ZigBee protocol features include support for multiple network topologies such as point—to—point, point—to—multipoint and mesh networks, low duty cycle which provides long battery life, low latency, direct sequence spread spectrum (DSSS) which provides up to 65,000 nodes per network, 128-bit AES encryption for secure data connections and collision avoidance, retries and acknowledgements .

Specifically, the XBee PRO S2B module was used as this has the technical specifications that met the application perquisites. It has the range up to 90m (indoor) and 3200m (outdoor) among other modules, its receiver sensitivity of—102dbm was also a plus factor [5].

GPRS/GSM module

GSM communication is a digital cellular telephone system designed to use the service of SS7 signaling and an all-digital data network called Integrated Services Digital Network (ISDN) [6].

GSM communication is used to send the data from the ZigBee gateway into remote server HANDA. The range of GSM then is unlimited. The main advantage of GSM is its range because any place on earth where mobile signals are present is a working area of GSM module. The whole earth is the range of a GSM communication.

Microcontroller

Arduino is an open-source physical computing platform based on a simple input/output board and a development environment that implement the process language. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button [7].In this study, it serves as the brain of the WAVES; it sends a command based on the data gathered from the sensor.

Solar power system

Solar power system required a power output of has a voltage of 12v DC and a power of 20w while the battery showed have voltage of 12v dc and should have capacity of 20 ah.

Formula for power consumption was also considered to be able to determine if the power system can sustain the power requirement of WAVES. For power, the current reading between the battery and load was multiplied by 12v and for the capacity of the battery, 100ah was divided by the current reading.

3. RESULTS AND DISCUSSION

Locally available components and materials were utilized in the design and development of the WAVES. The system has three major components: the sensor nodes, the central station and the wireless protocol.

Design and development of WAVES

The design and development of WAVES involved initial planning and conceptualization of prototype. The block diagram of the prototype, as contained in Figure 6 was prepared.

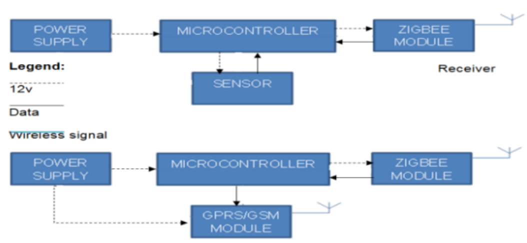

Figure 6. Block Diagram for WAVES sensor

The figure presents the components included in the development of the prototype. Electricity enters and is stored in the system by solar power system. This comprises the connection of all major components of the system including the solar panel, charge controller, battery, microcontroller, GSM / GPRS module, GSM antenna, ZigBee modules and ZigBee antenna. The energy stored in the battery is made available for consumption of the wet and dry sensors, microcontrollers, ZigBee modules, and GPRS/GSM module.

Design and development of the buoy

Figure 7 shows the design of the buoy; it is made of stainless steel, polyurethane and cement. The fiber glass coating was used to ensure the durability of the buoy.

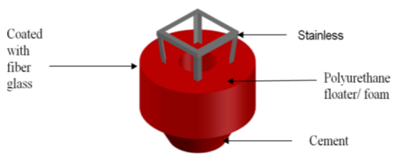

Figure 7. Design of Buoy

Testing and Evaluation

After the construction and wiring connection, the prototype was set for testing. In the testing of the prototype the all the system components considering each technical specification of materials used microcontroller, capacitive sensor, ZigBee modules and solar power system.

Testing of Wet and dry sensor

Four trials were conducted for the effectiveness and efficiency of wet and dry sensors inside a cylindrical glass tube. In every trial, the researchers used different materials such as clear plastic container, colored plastic container, clear glass container and colored glass container as a barrier between water and sensor.

Table 1 presents the results of each trial. The wet and dry sensors could detect water using plastic and glass barrier.

Table 1
Effectiveness and Efficiency Test for Wet and Dry Sensor

Trial	Wet	Dry	Result
1. Clear Plastic Bottle	On	Off	Passed
2. Colored Plastic Bottle	On	Off	Passed
3. Clear Glass Bottle	On	Off	Passed
4. Colored Glass Bottle	On	Off	Passed

ZigBee Communication Test

Table 2 shows the total time of receiving data of the ZigBee gateway as reflected from microcontroller serial monitor.

Table 2
Speed Test of ZigBee Gateway Receiving Data from Four Wet and Dry Sensors

Output of Serial Monitor	Time H:M:S	Total time of transmission
1234	00:00:01	1s
1234	00:00:02	1s
1234	00:00:03	1s
1234	00:00:04	1s
6234	00:00:06	2s
6734	00:00:08	2s
6784	00:00:10	2s
6789	00:00:12	2s
6789	00:00:12	1s

GSM Communication Initial Test

Table 3 shows an alert message was received when the wet and dry sensors changed their status from wet to dry or dry to wet. The accuracy of the GSM was tested by lifting and submerging the sensor so that the latter detects a wet and dry status, and then automatically sends messages to the registered numbers for the alert and monitoring of the sensor's status. The messages must be appropriate to the status of wet and dry sensors 1234 for wet and 6789 for dry.

Table 3. **Efficiency of Alert Message of Wet and Dry Sensor**

SMS	Status	Time received
WAVES is now online	Online	1:04 PM
1	Sensor1 submerged	1:04 PM
2	Sensor 1 submerged	1:04 PM
3	Sensor 1 submerged	1:04 PM
4	Sensor 1 submerged	1:04 PM
1234	SMS status hourly	2:04 PM
1234	SMS status hourly	2:05 PM
6	Sensor 1 lifted	2:32 PM
6234	SMS status hourly	3:04 PM
7	Sensor 2 lifted	3:20 PM
8	Sensor 3 lifted	3:25 PM
9	Sensor 4 lifted	3:33 PM
6789	SMS status hourly	4:06 PM
6789	SMS status hourly	5:04 PM

Final Testing of WAVE

Final testing of the functionality of the system was conducted. The purpose of functionality test was to identify if the hardware and data communication were compatible and worked smoothly when operated. Results in Table 4 show the WAVES sensor functioned 100% as designed.

Table 4
Final Testing of WAVES

SMS	Time	Status
1	1:02 PM	Normal status
2	1:02 PM	
3	1:02 PM	
4	1:02 PM	
9	1:34 PM	No tsunami alert / check sensor 4
6	2:14 PM	No tsunami alert/ Low Tide
7	2:40 PM	
8	3:30 PM	
9	4:45 PM	
6	6:14 PM	No tsunami alert / check all the sensors
7	5:50 PM	
8	5:43 PM	
9	4:50 PM	
7	6:31 PM	Tsunami detected
8	6:32 PM	
9	6:32 PM	
6	7:30 PM	Tsunami detected
7	7:30 PM	
8	7:31 PM	
9	7:31 PM	

4. CONCLUSIONS

After thorough testing and evaluations of the system, the following conclusions are drawn.

The sensor nodes composed of capacitive sensor arrays can effectively detect possible presence of tsunami. Based on the simulation conducted it can detect the receding sea water level which is a sign of impending tsunami. The effective distances of the sensor array, for the system to work are 25m, 50m, 75, m and 100 m away from the seashore. The combined ZigBee and GSM wireless protocol is effective in transmitting the status of the sensors which indicate the possible occurrence of tsunami. The test on functionality of the system shows system hardware and software work compatibly.

5. RECOMMENDATIONS

Based on the findings and conclusions of the study, the following recommendations were given: (1) Add decision support system in the gateway that can interpret the data coming from the sensor specifically numbers 1234, 6789 and letters ABCD; (2) Use postpaid subscription to a mobile network to avoid loading time to time; (3) Develop a GSM module program that can receive messages from authorized person to be able to change the messaging status interval; and (4) Add P2P network to be able to transfer data from gateway to remote server in times of system down of GSM communication.

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