Advance Waterway Transport System Based on Internet of Things (IoT)

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A thesis submitted to the Department of Computer Science and Engineering
in partial fulfillment of the requirements for the degree of
B.Sc. in Computer Science

Department of Computer Science and Engineering

Brac University

September 2022

Declaration

It is hereby declared that

1. The thesis submitted is our own original work while completing degree at BRAC University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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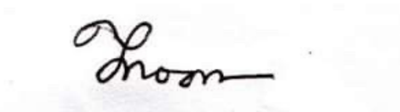

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Abstract

Nowadays the inland waterway transportation sector has grown significantly in recent years, offering a large possible contribution to environmentally friendly and cost-effective transportation to reduce congestion on the roads. Accidents in developing nations' waterways occur on a daily basis all throughout the year. A total of 320 incidents resulted in the deaths of 496 people between 2014 and 2020, while 5425 accidents resulted in 6220 injuries. So, the need to develop a much more safe, secure, and efficient system is greater than ever. In this paper, we proposed a system to ensure safety in inland waterways using IoT to unlock new way for developing waterway transportation. We are using different type of sensors and protocols to collect data. Weight calculation using load line image processing system, automated speed and distance control system over vessels using ACC model is introduced. Also, a list of priority data encoding system is proposed. Control room is monitoring data and a post accident methodology to ensure safety. This model can be proven very effective in reducing the number of dreadful fatalities happening every year across the world in inland waterway transportation.

Keywords: IoT; Waterway Transport; Control Room; Architecture; Obstacle Detection;

Acknowledgement

Firstly, all praise to the Almighty for whom our thesis have been completed without any major interruption.
Secondly, to our advisor Jannatun Noor Mukta madam for her kind support and advice in our work. She helped us whenever we needed help.
And finally to our parents without their throughout support it may not be possible. With their kind support and prayer we are now on the verge of our graduation.

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Chapter 1

Introduction

Since the dawn of every civilization, the waterway transportation system has been developing its significance rapidly. In particular, in the Southeast Asia region, where rivers and canals make up a huge portion of the country, inland waterway transport plays a vital role in its economy and logistics. Bangladesh's territorial waters cover roughly 9,000 square kilometers with a 720-kilometer coast line and a 20,000-square-kilometer economic resource zone (ERZ) in the sea. Nearly 60,000 people travel via different modes of inland transportation, including watercraft, to get to their destinations on an annual basis. Inland vessels in the nation include passenger ships, ferries, country boats, trawlers, speedboats, sand haulers and freight carriers among the many types of vessels. The interior waterways of the nation are home to 12,960 registered inland watercraft.

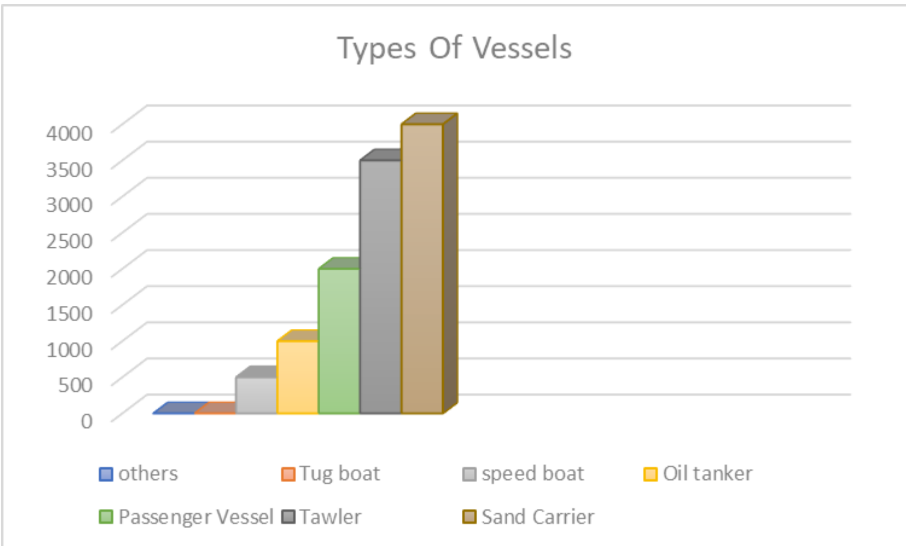

Figure 1.1: Number of different types of Vessels

Internet of Things (IoT) refers to the process of connecting physical components and communication between internet-connected devices to gather, share and process data. Using IoT and other advanced technologies at their best to implement and ensure safety to advance water transportation is the motive of this paper.

In the Figure 1.2, a fire broke out in the engine room of the launch MV Abhijan-10 on 24th December.

Figure 1.2: Fire accident in launch [42]

1.1 Motivation

Bangladesh's navigable waterways, which span 5,968 kilometers, were classed in 1989 based on the least available draft (LAD) [42]. Inland Water Transport (IWT) accounts for 30% of total freight transport performance and 20% of passenger transport and has a significant impact on Bangladesh's transport system. Despite the very low level of service, the demand for domestic water transport is very high due to its low cost and easy access compared to other options [16]. Collisions accounted for 61.72 percent of all canal incidents from 2008 to 2019, according to statistics published in the Journal of International Maritime Safety, Environmental affairs, and Shipping in 2021.These accidents were responsible for 53% of fatalities and 46.5 percent of injuries on waterways[19].

On December 24th, 2021, a fire broke out in the engine room of the launch MV Abhijan-10. According to police, a crowded ferry in southern Bangladesh caught fire, killing 39 people and injuring 70 others. In eastern Bangladesh, a passenger boat and a cargo ship carrying sand collided in August, killing at least 21 people [6].

Figure 1.3: Fire broke out in MV Abhijan-10 [45]

Figure 1.4: Cargo ship drags and sinks ferry in Bangladesh [49]

A fire aboard a boat operating in a remote southern section of the nation killed at least 49 people and wounded many more in December 2021. Another boat catastrophe killed 21 people in August 2021 and another ferry collision killed 27 people in April 2021. In developed countries, ship management systems have already decreased their accident rate but in developing countries like Bangladesh, India is still facing accidents in waterway transport.

1.2 Research Aim

For Bangladesh, as a densely populated country, the parameter of safety in waterway transportation is mostly compromised for several major reasons, like:

1. Congestion and overloading in vessels, launches, ferries, small ships.
2. Improper boat handling and an unregulated increase in the number of vessels on the waterways.
3. Lack of proper lighting, inexperienced captains and crew members, and subpar means of communication and navigation.
4. Lack of an overall supervision control system on the vessels.
5. Lack of an accurate weather forecast system.
6. Lack of maintenance.

Analyzing some of the many incidents happening in Bangladesh, we can determine that the waterway transport fatalities are taking many lives each year but still there has not been any significant change in this matter. Throughout this paper, we are analyzing and using advanced IoT and other technologies to develop a proper and adequate water transport system to ensure safety and effective solutions to ensure mobility.

1.3 Research Problem

More than a few rivers may be found in Bangladesh. The use of waterways for human travel is essential. Transport by water is abundant in Bangladesh. There are over 1.57 million passenger-kilometers generated for every kilometer of inland waterway route [4]. The number of accidents seems to rise every year. Many lives have been tragically lost as a result of accidents on this canal. With so many incidents occurring annually, it is crucial to identify the cause of these mishaps. In this study, we explore possible answers to this problem. In-vehicle malfunctions or external environmental factors like bad weather can also contribute to transportation accidents. There are a variety of mishaps that can occur on Bangladesh's waterways. Accidents, storms, overloads, power surges and electrical surges are all potential causes [44]. There are several rivers in Bangladesh. The use of waterways for human travel is essential. There are numerous modes of water transportation in Bangladesh. Activity on the nation's interior waterways has increased to the tune of over 1.57 million passenger-kilometers per kilometer of waterway route [4]. As the world's population rises, so does the congestion on the world's waterways. Passengers are piling into transportation vehicles. Most motorists are clueless about the weather. In certain cases, they don't bother to make sure the transfers are safe.

According to one study that focused solely on Dhaka, over 250,000 people use Buriganga and Turag every year[49]. Landing pads, however, are subpar.

The yearly rate of accidents is rising quickly. A tragic number of lives were lost in this canal disaster. Transport accidents can be caused by both mechanical issues and external factors like bad weather. Accidents on Bangladesh's waterways can take many forms. Overload, high current, cyclone/storm, collision and physical failure are some of the causes [44].

According to study [44], 44% of accidents can be attributed to adverse weather and overloading, 9% to excessive current, 4% to physical failure, 39% to collisions, and 4% to other reasons. Forty-four percent of all incidents involve vessels ranging in length from 40 to 60 meters [4]. When two or more vehicles fail to keep a safe distance from one another or travel at an unsafe pace, accidents can and do occur. Any sort of collision, including those at high speeds, can lead to an accident. When authorities neglect to inspect the mechanical health of a vehicle before sending it on its way, a physical failure accident may occur. As the number of passengers on a bus, train, or airplane approaches or exceeds its capacity, the risk of an incident increases. Sometimes motorists are unaware of the impending weather.

Given the frequency with which such incidents occur, it is crucial that we discover how to prevent them. If we do not figure out how to prevent them, accidents will rise in the days ahead. In this situation, the Internet of Things can aid in the reduction of such mishaps. This study is an attempt to discover the cause and remedy for such mishaps.

1.4 Research Objectives

The prevention of accidents on waterways is the primary focus of this investigation that we are conducting. Each year, individuals lose their lives as a result of the inadequate transit infrastructure for waterways. We are making an effort to investigate the cause of the problem and locate a solution that is based on IoT. As a result, we will work on designing an infrastructure for a transportation system that uses rivers safely. This research will assist in gaining a better understanding of the significance of the IoT. In order to monitor the movement of the waterway cargo, we will employ certain sensors. The Internet of Things devices are acting as sensors; they will collect the data and then transmit it on to be processed further. The primary aim of the research are to:

1. To get an in-depth understanding of the transportation system using waterways.
2. To be aware of the significance of the Internet of Things and to incorporate it into the waterway transportation system.
3. To develop an infrastructure for the waterway transportation system in order to cut down on the number of accidents.

1.5 Problem Statement

Our solution has the potential to improve the security of the inland waterway transportation infrastructure. The number of accidents that occur in waterways continues to rise. As a result, a great number of people are losing their lives. This system has the potential to increase the level of safety on the waterway. This method is able to determine whether or not there is a chance of an accident occurring. When there is another transport nearby, it can make it difficult for the driver of one transport to operate their own vehicle. In this instance, our algorithm is able to determine the appropriate level of speed for that transport. In addition, the implementation of our technology has the potential to reduce the number of collisions involving transporters. In the event that an accident does take place, the post-crash module has the potential to reduce the amount of damage sustained by passengers and transport. In the event of any mishap, a search and rescue crew will be dispatched. They are able to travel to that location and lend a hand in the effort to save those people and transport. By utilizing this method, a control center will have the ability to monitor all of the different transports. In addition, we make use of surveillance techniques within our system.

Statistics of some accidents due to collision:

	Date	Accident	Reason
2011-2015	April 21, 2011	A ship carrying one hundred passengers and departing from Bhairab in the direction of Jamalganj was involved in a collision with a shipwreck that resulted in the deaths of twenty-four individuals [47].	Collision
	March 12, 2012	The ship MV Shariatpur 1, which was carrying 250 passengers, capsized in the Meghna river, resulting in the deaths of 147 persons. After being involved in a collision with a cargo ship, the incident took place [11].	Collision
	February 8, 2013	A ferry that was carrying more than fifty people went down in a river close to the Munshiganj neighborhood after having a collision with a sand barge. The episode resulted in the deaths of 14 persons and the disappearance of several others [14].	Collision
	February 23, 2015	A ship carrying 140 passengers was involved in a collision with a cargo ship and sank in a river in Bangladesh. As a result of the accident, 69 persons were killed, while numerous others remain missing [18].	Collision

2016-Present	June 29, 2020	At around 8:55 a.m., the larger ferry Mayur-2 collided with the smaller ferry MV Morning Bird, causing both vessels to sink into the Buriganga River. The MV Morning Bird was carrying up to sixty passengers at the time of the accident. At least 34 people were killed as a result of the tragedy [34].	Collision
	4 April, 2021	ML Sabit Al Hasan with 50 passengers capsized in the Shitalakkhya river in Narayanganj district. The incident killed 34 people [43].	Collision
	May 3, 2021	A speedboat traveling from the Munshiganj District to the Madaripur District collided with a sand-laden bulk transport, resulting in the deaths of at least 26 individuals. Up to this point, five injured people, including three children, have been pulled from the speedboat, which had been carrying a total of 36 passengers [41]. On the other hand, it is thought that five others are still missing [40].	Collision
	January 5, 2022	A trawler that was carrying seventy persons was involved in a collision with the ferry MV Farhan-6 in the Meghna river, and it sank as a result of the collision [48].	Collision

Table 1.1: Statistics of some collision type accident

In table 1.1, all off the accident reason is collision. If our system was implemented in those ship/launce, it could avoid collision. Because we implemented sonar sensor in our system and it could detect obstacle and distance of obstacle would be showed in the web server of control room.

1.6 Our Contribution

We developed an architecture using IoT that can be implemented using a minimum amount of resources as underdeveloped countries often spend less money on research and development. We have made the following contributions to this study based on our research:

1. We propose an advanced waterway system, our architecture will offer automated speed and distance control over vessels only in times of the possibility of occurring accidents. To perform this solution, we are using Adaptive Cruise Control (ACC). The ACC system has been developed to automatically change the speed and distance.

2. A large amount of data which sensors will be generating continuously. But in this architecture, among all data we will select only a few relevant priority data. These priority data will be encoded into 8 bits as a form of data compression. This type of data compression will be effective in terms of lessening a significant amount of space consumption.

3. We propose an automated weight calculation system, where whether the ship is overloaded or not will be visible in the data server and also to the operation manager of the control room. Overload creates many accidents in waterways which will be reduced by using this system correctly.

4. We are using different sensors for temperature, fire and smoke detection. Forward Looking Sonar (FLS) and algorithms are used in this model for the underwater depth calculation.

5. Our model will keep track of the location and will show the nearest rescue team locations as well as inform the central control room in times of accidents. GPS, satellite-based navigation will allow the vessels to navigate accurately in riverways. This will ensure much less time to gain assistance during any fatalities or accidents.

1.7 Overview of Thesis

In chapter 2, we will discuss IoT architecture and the communication protocols for sensors. In chapter 3, we will discuss our literature review. This chapter will demonstrate related works of our thesis. Different papers work with GPS-GSM based vehicle tracking system, Inland water transport system in short IWTS, passenger vessels operating on Bangladesh's inland waterways using a GIS. In chapter 4,we will discuss our methodology where we will focus on our own work regarding system architecture, weight calculation, obstacle detection, speed distance control, monitoring & emergency alarm system and post accident system. In architecture, we will propose a control room with IoT functionalities such as obstacle detection and speed control to prevent accidents. Also, we will elaborately discuss the works of the control room and its necessity. In chapter 5, we will show a comparative analysis about weight calculation and communication protocol of different papers for reasoning why our choice of weight calculation and communication protocol is better. Moreover, we will highlight our results of implementation and findings. In chapter 6, we will discuss our initial model, field work and limitations. In chapter 7, we will conclude our work with a future work for a smart docking system.

Chapter 2

Background

2.1 IoT Architecture

Everything from radio frequency identification (RFID) tags to infrared sensors, global positioning systems, laser scanners, and more can be connected to the internet through a communication protocol and various data-detecting devices. It can exchange data, communicate, identify objects intelligently, use positioning techniques, be tracked, monitored, and managed.

2.1.1 Key Technologies

- **RFID Technology:** It's like a "register" of marked and identified objects, and it's useful for querying.
- **Sensor Technology:** It is the IoT's "senses" that supply the most unique data
- **Embedded Technology:** It has the potential to give IoT items some intelligence. Nanotechnology allows smaller volume objects to communicate and link, lowering system consumption.

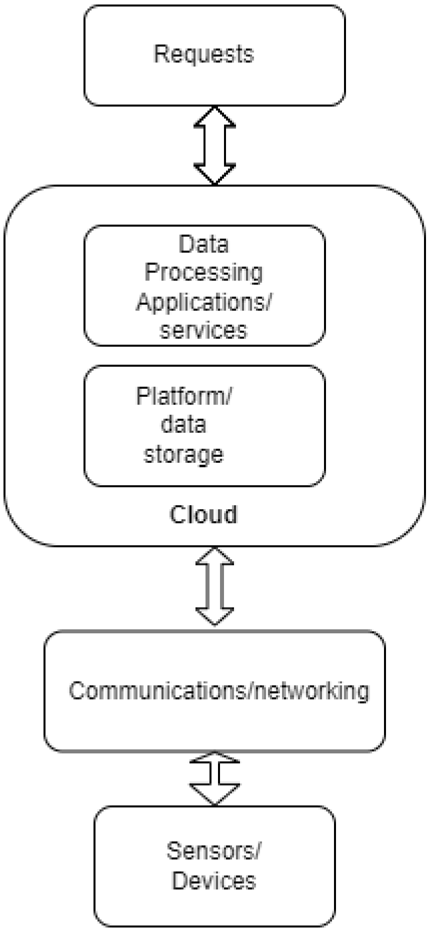

Figure 2.1: IoT working structure

2.1.2 IoT Data Analysis

An Internet of Things sensor network is characterized by its distributed nodes, each of which is responsible for carrying out the same function. It is necessary for the various IoT-based application services to merge or combine data from several sensors in order to achieve a higher level of precision [2].

Real-time processing accounts for the vast majority of the Internet of Things sensor data used in industrial applications. It is necessary to treat sensitive data in order to clear up any ambiguities that may arise during further data analysis in order to gain knowledge and make judgments [37]. The functions of data denoising, data outlier identification, missing data imputation, and data aggregation are some of the functions that the data processing layer seeks to accomplish. It is necessary to have a data fusion layer in order to manage the many sensor data issues that are caused by the existence of a wide variety of heterogeneous sensor devices. The goal of data fusion is to combine the actual sensor data collected by a number of Internet of Things sensor devices. The data analysis layer compiles information from a variety of sources into a unified format with the purpose of improving the quality of knowledge construction and decision-making.

2.1.3 Basic Architecture

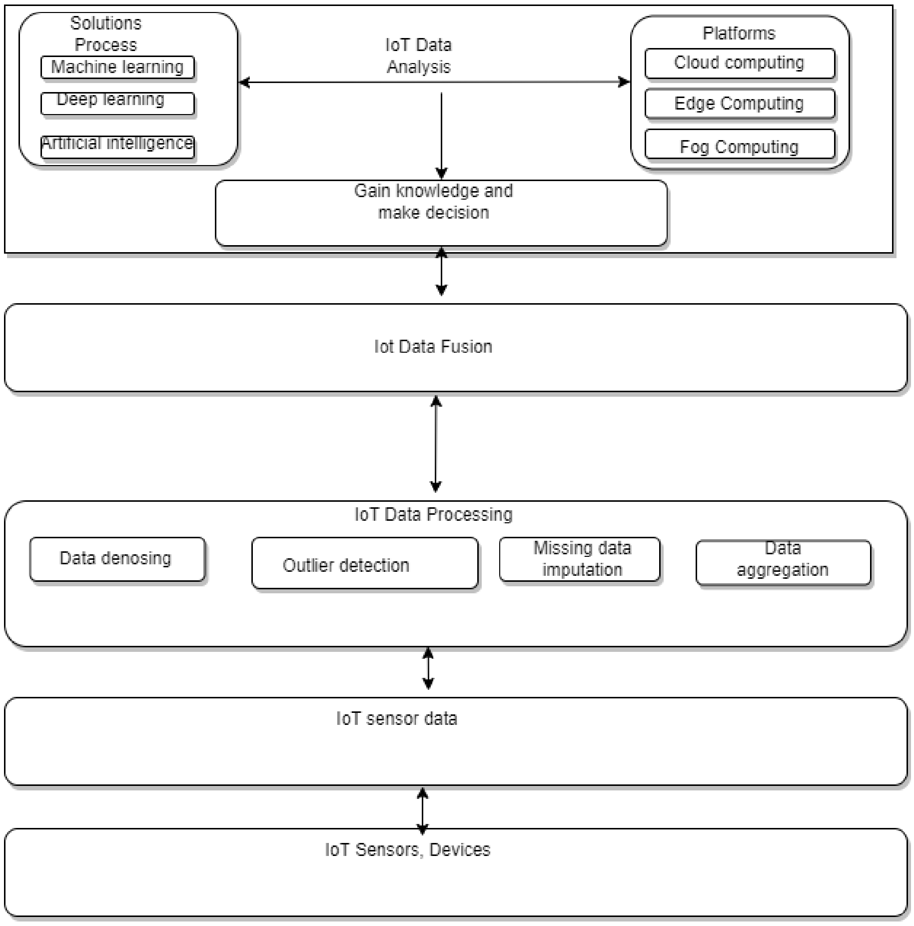

Figure 2.2: The basic architecture for IoT sensor data processing

In Figure: 2.2, it refers how IoT data analysis and data processing works.

2.1.4 Process

Increasing the energy efficiency of M2M devices require the use of a centralized data processing method known as cloud computing. This is due to the fact that sensor-based M2M devices only sense information and perform very little calculation. On the primary application server, the intricate data computation is carried out. Notifications are sent to the moving vehicle and any other systems that are active utilizing GPRS technology.

After receiving data from the vehicle's sensors, it conducts an analysis and analysis of the information using an emergency prediction system that was created and trained using a variety of data mining methods (e.g., data fusion algorithms , Bayesian Belief Network).

After processing the data using the internet and GPRS technology, it delivers the vital information to the control unit of the moving vehicle, the station terminal and the transportation authority.

2.2 Communication Protocol for Sensor

The term "LoRa" (short for"Long Rang") refers to a type of wireless sensor network (WSN) in which data packets with transfer rates between 0.3 kilobits per second and 5.5 kilobits per second are sent from a low-power transmitter to a receiver over a considerable distance using a low-power wide-area network (LPWAN) [31]. Low-power wide-area networks (LPWAN) enable long-distance connections with low bandwidth [28]. This method satisfies the needs of the Internet of Things, including the use of remote nodes and nodes powered by batteries. Instead of using a narrow frequency range, LoRa signals are typically broadcast at 125 kHz or higher [27]. The three primary functional aspects of LoRa are the Code Rate (CR), Spreading Factor (SF), and Bandwidth (BW) [20]. LoRa gateways can manage hundreds of connected devices simultaneously. An antenna-equipped radio module and a data-processing microcontroller make up the two main components of a LoRa end node. Internet gateways are similar to regular desktop computers, except that they are powered by an external power source. The data from a single end node can be received by several gateways. LoRa uses a star topology for its network design. Both sending and receiving data are possible thanks to the two-way connection between the end node and the gateway.

LoRa was chosen for our project because it is a spectrum modulation [1] that uses frequency over time to encode information and transmits data in real time across a large area while using relatively little power and not requiring a license fee.

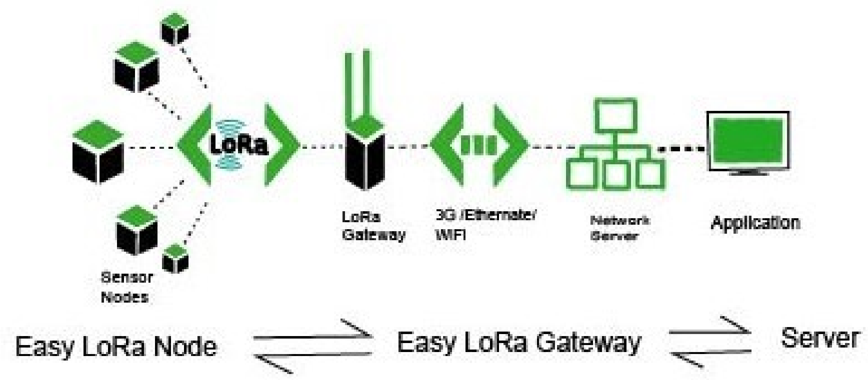

Figure 2.3: Lora communication protocol overview

2.2.1 Process

Firstly, the sensors will collect data, which is attached to the LoRa development board. On the LoRa development board, the microcontroller and LoRa radio module are integrated on a Printed Circuit Board (PCB). We are using our own LoRa development board using an Arduino Uno, a radio LoRa module, and a breadboard. There are several LoRa and end-node libraries that we will use in our project, such as the IBM LMIC library. We will register our gateway for the application server in the control room and in the Things Stacks Community Edition network by providing a gateway id, name, and API key. To activate our end device, we used the Over-The-Air-Activation (OTAA) method because it provides the most secure way to connect an end device to a network server. We will store the DevEUI, AppEUI, and AppKey in the end device before activation and the same AppKey in the network server. DevEUI is for uniquely identifying the end device similar to a MAC address, and AppEUI is for uniquely identifying the application server like a port number. The AppKey (an AES 128 bit symmetric key) is utilized for Message Integrity Code (MIC) to ensure the integrity of the message. The DevNonce is generated by the end device, which is a randomly generated number to prevent the rough devices from replaying the joint request.

2.3 GPS

A system that enables precise location determination is referred to as a global positioning system, or GPS, for short. In terms of the precision with which it can measure the outcomes of the Earth's rotation parameters, GPS is on par with SLR and VLBI. The length of time it takes to receive a signal that has been delivered is multiplied by the distance that separates each satellite in this system. For the GPS receiver to be able to track movement and figure out where something is in two dimensions, it has to lock on to the radio signals of at least three satellites.

In its most fundamental form, GPS determines your location by triangulating the distance between at least four satellites to arrive at its conclusion. It calculates its position as the point where the rings meet by keeping track of the locations of its satellites and imagining a ring surrounding each of those locations.

2.3.1 AIS (Automated Identification System)

The Automatic Identification System (AIS) makes use of a transponder system that transmits data using the VHF maritime band. This system is able to broadcast data such as ship identification, geographic location, vessel type and cargo information in real time between ships and between ships and the shore. As a result of the fact that these messages include the ship's GPS position, all significant information regarding the movements and contents of the vessel may be rapidly posted to computerized maps. The use of this technology considerably improves the safety and security aboard the vessel.

Chapter 3

Literature Review

According to study [20], the Intelligent Water Transportation System, also known as IWTS, is used to monitor all of the transportation that occurs on waterways. IWTS is used to do routine checks on the vehicles that are allowed on waterways. IoT technology was utilized in the construction of this system. Nevertheless, there are a few aspects of this method that are tricky to put into practice. Because real data is not readily available, we will have a more difficult time collecting it.

In light of the findings presented in this study [23], a new vehicle tracking system that utilizes GPS and GSM has been developed. It has the capability to monitor the velocity and orientation of the vessel from a remote location. Using the Global Positioning System to track movement, the device can find accidents and send the current GPS coordinates to the right people or the owner of the vessel right away.

In addition to that, they were able to interact with ground control via the ship-mounted device by using the GSM network. Additionally, the authors are working on a gadget that utilizes GPS in order to track the location of the launch in the event of an emergency. In the event of an accident, it will show the location of the launch as it was just before it occurred. There are many other capabilities of the device that can be utilized. These include the identification of an overload launch, the prediction of the weather and the detection of an item.

The robust system is able to identify ships that are carrying an excessive amount of cargo, as indicated by paper [15]. According to Kalman filter and digital image processing, there has been the development of a method that comprises three stages: the detection of ships, the tracking of ships and the identification of overloaded ships. The creators of the project are utilizing four distinct aspects of the Internet of Things in order to finish the project. They are overburdened with responsibilities including the identification of objects, monitoring of locations, the detection of ships and the forecasting of weather.

This study [39] proposed a system that would consist of four components: GPS tracking, overload detection, object identification, and weather forecasting. Together they would make up the system. The Internet of Things gadget that is being proposed may identify things in order to avoid collisions, determine whether or not a launch was successful, find an accident and make weather predictions.

The topic of accidents was discussed in most of the papers, which was not surprising. Despite this, they did not provide the best available choice. The purpose of this research is to uncover the accident characteristics and design of Bangladesh's inland waterways, with a particular emphasis on collision types of accidents [9]. They proposed that improvements should be made to weather forecasting systems in order to reduce the number of accidents of this kind that are caused by cyclones. Additionally, enforcement might be tightened up so that people are discouraged from working in unfavorable weather. On the other hand, an Internet of Things-based weather forecasting system is described in detail in a research paper [42]. According to [19], they devised several responses, but it appears that such responses are not the correct ones. They recommended that the means of transportation not be overloaded, that life jackets be made available and that the vessels be maintained. Because of this, it was suggested that AI could be used to solve this problem.

According to study [7], the purpose of their study was to develop an effective method that would provide information to ship commanders regarding whether or not their vessel had exceeded the maximum allowable weight for it. They came up with a list of twelve possible solutions to the problem. There were three suggestions made regarding how to stop passenger vessels from being overloaded. These methodologies are referred to as weight estimation methods and average weight methods, respectively.

In this particular investigation, GPS [29] was utilized. This piece of paper The Global Positioning System monitoring system is a multi-functional platform that is capable of fully leveraging the benefits offered by the internet to meet the requirements of open platforms. The functions of management, monitoring, placement, inquiry, alert, and communication are just some of the ones that are offered by it. Any organization that is working on the topic of the development of water resources ought to have access to this cutting-edge technology that is both straightforward and effective. Water engineers and planners would benefit immensely from having access to an up-to-date digital database on water resources, which would be much simpler to compile as a result of this change [33]. Implementing a 5G maritime transportation intelligent platform increases the reliability, applicability and value of ship data, as stated in the paper [35]. Anomalies and irregularities in the operation of inland passenger vessels were brought to light by Baten (2005), who focused on the inland water transport infrastructure in Bangladesh. Chowdhury (2005) analyzed the activities of legal and informal motorized passenger vessels operating on Bangladesh's inland waterways using a Geographical Information System (GIS).

Using M2M technology in a network, which can transfer critical information in a flash, there is a terrific way to communicate with one machine to another machine according to [30]. Control room employees can quickly communicate with any moving vehicle captain or rescue vehicle captain via the voice sensor network. This research demonstrates that real-time people counting using depth photography is an accurate method [16], which we can utilize to compute the weight of an air deck using an Arduino. Sensors and actuators, as well as computers and mobile phones, can communicate via a network via M2M communication, also known as machine type communication (MTC). M2M communication is a vital technology for exchanging data between sensors and actuators to assist with a wide range of jobs. Smart infrastructure management, surveillance and security, e-Health, and municipal automation applications). Huge amounts of machine-to-machine connection are being aided. The (MTC) gadget is one of the most complex devices to create. The challenge is to discover a cost-effective way to accommodate multiple people. Network access and traffic congestion reduction [49]. In a real-time machine-to-machine communication architecture system based on LTE, Navid and Srdjan propose how latency might be further lowered .

The most efficient method of data compression is Run Length Encoding (RLE). Because it has a large compression capacity and gives a precise output with a simple implementation method, Run Length Encoding (RLE) is utilized for data compression. The purpose is to reduce the size of the input data by using a lossless compression method. It is more energy efficient and has a faster response time [10]. Information is stored in bits, which are patterns of 0s and 1s. The alphabet (a, e, r, and t) would require two bits per character if all characters were the same size. As a result, all of the characters in the line “A rat ate a pastry at a tea” might be encoded using 2 18 = 36 bits. Because the letter ”a” is the most prevalent in this text, a variable-length binary code like a = 0, t = 10, r = 110, e = 111 with “t” as the second most common letter, will result in a flattened message of only 32 bits. The most significant property of this encoding is that no code is a prefix of another. That is, no extra bits are required to distinguish letters [10].

Chapter 4

Methodology

The purpose of this “Advanced Waterway Safety Transport System based on IoT” is to ensure management and safety with advanced technology. We are using an IoT based control room system connected with waterway transport and the nearest safety control room. The update of the waterway transport will be sent to the authorities every 10 minutes to ensure its safety. There will be an advanced monitoring system which will warn about the weight, fire extinguisher checker, communication protocols, image processing, ACC speed control, maintenance validity of the ship to the authorities and waterway transport management. The HF sonar will detect obstacles and will avoid them by lowering speed or changing route using OAS. Here, we will be describing the features.

4.1 System Architecture

We present work on a continuous process which will generate and share real-time data for maintaining a normal or correct situation. For a ship, this is a scheduled process where it needs to start its journey by taking permission from the control room, sharing its real-time data from time to time on its way to reach its destination safely.

Before 10 minutes of starting its journey, all the safety measures of the ship will be checked by the control room in charge. The captain will ask for permission from the control room in charge by using voice communication. The captain can start the journey only when the control room in charge gives him permission by checking all the safety measures. After starting its journey, the ship will generate and share its information in a 10 minute timestamp continuously. The ship includes some sensors for temperature, location, obstacle detection, weather, etc., which will provide information to the control room. All the data from sensors will be transferred by using the LoRa protocol to the server and will be added to the database. After that, the data will be visible to the control room monitor by using the web page display module. The control room monitor will show all the moving vehicles in the map animation interface. When an emergency situation is created on a ship, an alarm will ring and the ship’s mark will be changed to red. The person in charge of the control room will check its web page display to identify the emergency situation. After that, he will communicate with the rescue team and others helping hand over voice communication to prevent the emergency situation.

In Figure 4.1, it refers to the overall system architecture of our system.

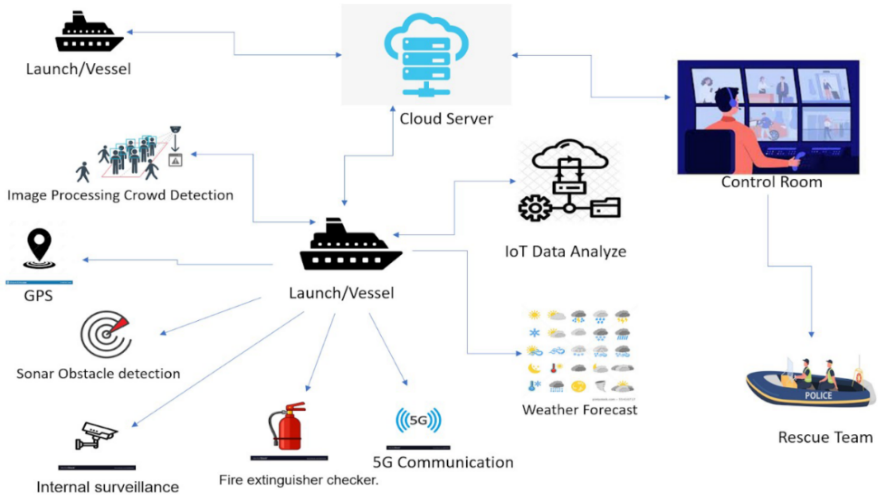

Figure 4.1: System Architecture

4.2 Weight Calculation

A large number of tourists travel by ship on various occasions. To monitor whether the ship is becoming overloaded or not, we will implement a real-time automated load line checker. A unique load line sign will be displayed on each ship. As part of this system, time-stamped cameras will be set up at various vantage points throughout the dockyard, providing a picture of the load line for each ship that will be sent to the monitor of the control room. In our control room computer, there will be equipped with a real-time sign recognition system [24]. Time-stamped camera will be connected with the control room monitor to send load line pictures. Figure 4.2, shows our testing images which we trained by image processing algorithm and also made by inspiring from load line signs of different cargo ships.

The entire procedure is broken down into two distinct phases: the detection phase and the classification phase. In order to compare captured photos to trained data sets of various distinct signs, some training data sets of such signs will be created. The algorithm for recognizing signs works by breaking down the input frame into smaller independently-processed chunks. Each sign will be placed in a way that if it is detected by image processing, then the ship is not overloaded otherwise it is overloaded. By identifying each ship by its individual call sign, this procedure will define the weight situation to each ship's data server. The computer used for image processing will be connected to the server through a TCP/IP socket, and the results of the image processing will be transferred to the database of each ship on the server. Along with this, detection result will be visible to the operation manager of the control room so that he can use it to give the permission to the captain of the ship to start.

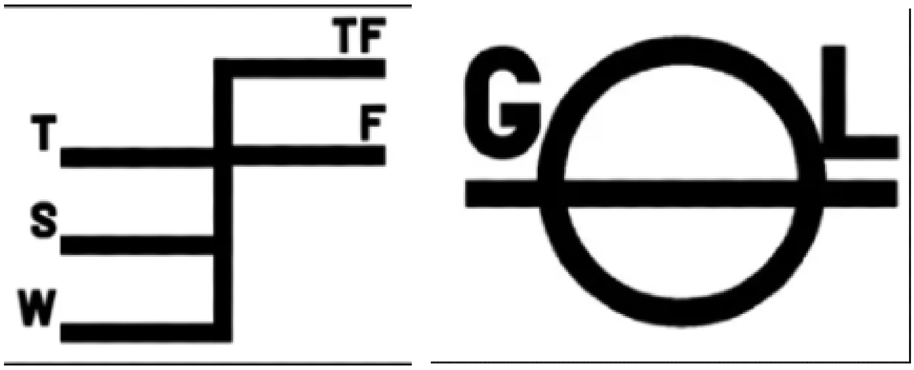

Figure 4.2: Training Images

4.3 Obstacle Detection

In obstacle detection, we are using Sonar. We are going to use forward-looking sonar (FLS). The B&G Forward Scan includes a 31mm, 180kHz transducer that scans the seabed at a 15° horizontal arc up to 90m in front of the boat and is designed to seamlessly interface with their own plotters. As the ship travel into shallower water, the range decreases substantially, giving us a range of around 4 times the depth. In murky conditions, it sometimes has trouble recognizing the seabed. The depth information is shown on a two-dimensional graph that depicts the region in front of the boat [9].

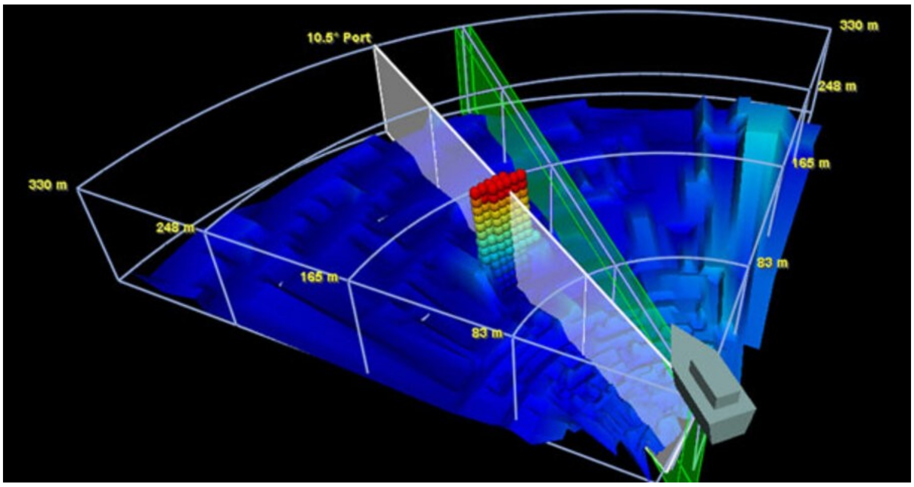

Figure 4.3: FLS covering the range [9]

4.3.1 Identical Cameras and Digitizers

Processing high-intensity images and locating correspondence is going to be significantly simplified thanks to the utilization of cameras and digitizers that are functionally equivalent to one another. The disparity in focal lengths between the lenses of the stereo camera results in the introduction of a 3D affine transform.

4.4 Speed-Distance Control

From the statistics, we have found that one of the major reasons for collisions in inland waterway transportation vessels is the lack of adequate control over the speed and distance maintained by the vessels' captains while steering.

According to our survey, most of the accidents involving collisions have been the result of manual reckless steering. So, to solve this issue, we need to have control over the speed and distance maintained by vessels while on voyage. As we are proposing an advanced waterway system, our architecture will offer automated speed and distance control over vessels only in times of the possibility of occurring accidents. To perform this solution, we are using Adaptive Cruise Control (ACC).

Adaptive cruise control (ACC) is a technology that assists automobiles in maintaining a safe following distance and adhering to speed limits. The system controls the accelerator, engine powertrain and brakes to keep the boat at a certain distance from the boats in front of it [3].

4.4.1 Constraints Proposals

Based on our research, we are proposing few constraints which are necessary for our architecture to function Adaptive Cruise Control (ACC).They are:

1. ACC will be applied at least 10-15 min after the start of the voyage. As in Bangladesh, until that time is required for vessel/launch to depart from high traffic terminals, vessels must be steered manually.
2. ACC will be turned off 10-15 minutes before the dock arrives. As vessels need to be steered manually at that time.
3. The ACC will overdrive the control system only at a time when significant data from sensors shows the possibility of collision.
4. The central control room will be notified before and after severe cases of ACC overdrive.
5. The ACC system can be turned off while awaiting authorization from the central control room.

The ACC system has been developed to automatically change the speed and distance. Sensor technology put into automobiles, such as cameras, lasers and radar equipment, allows ACC to calculate the distance between two vehicles or other objects. This model will allow vessels to sense the nearest vessels or objects automatically. With these sensor technologies, the vehicle can tell the captain about possible crashes in front of it.

Because ACC is already in many cars of various brands but has not yet been implemented in vessels, we can apply the same principles to vessels/launches on a larger scale.

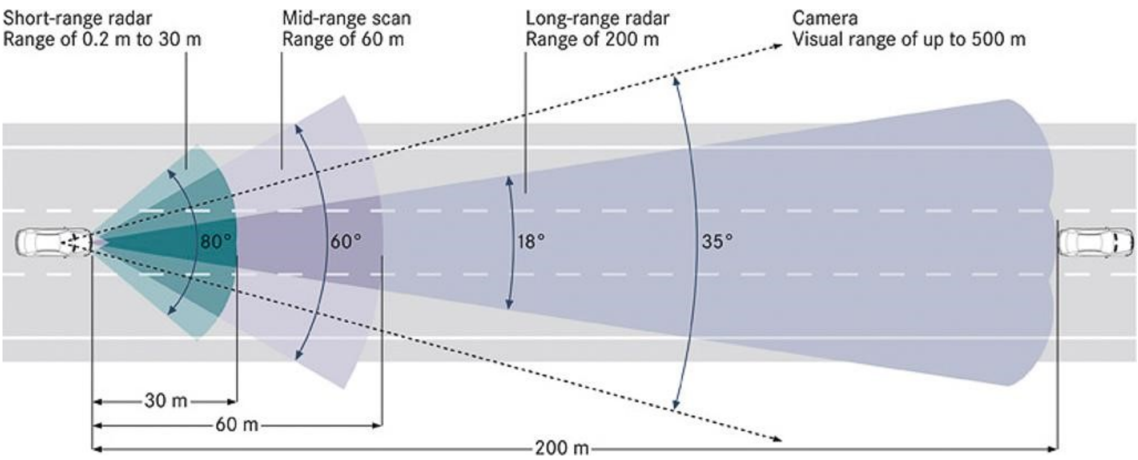

Figure 4.4: ACC system (1)

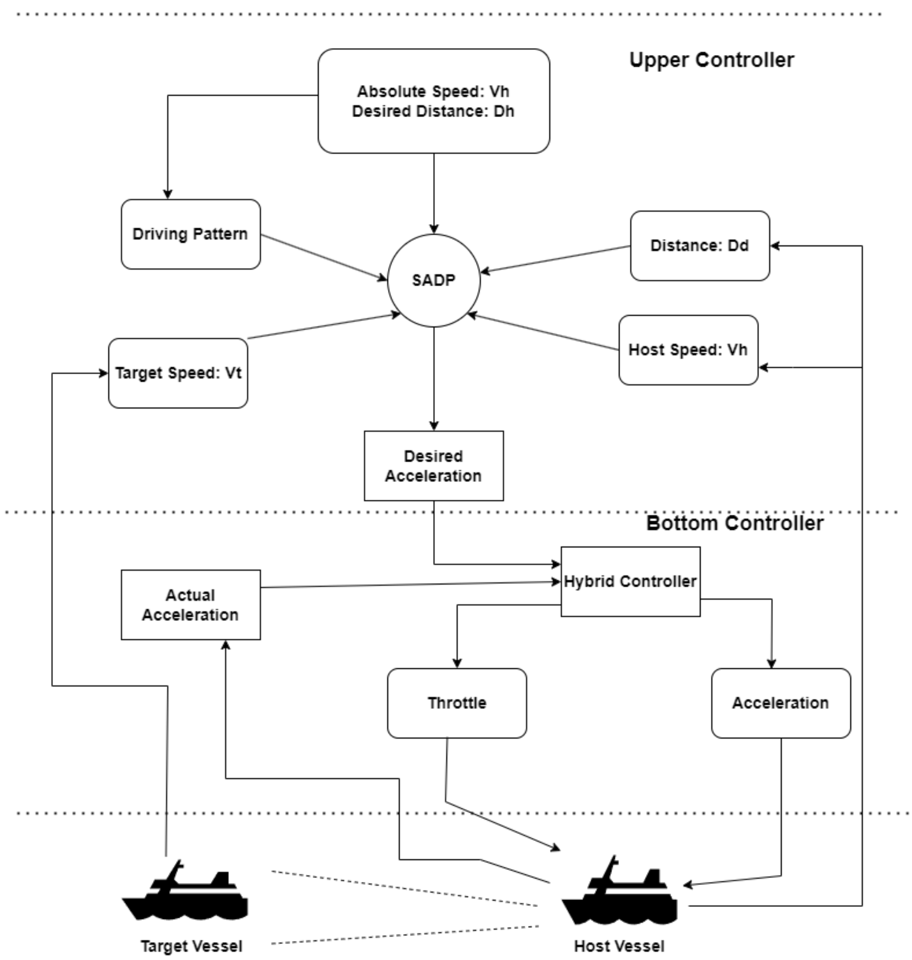

Figure 4.5: ACC system (2)

As we need to keep track of the speed-distance of both the host and target vehicle at the same time to keep them in a safe range to avoid collision or overdrive situations. We will have to calculate relative speed and relative distance.

1. **Relative speed:** The speed of a moving body with respect to another.

Vh-Vt..........(i)

2. **Relative distance:** The distance to cover after deducting the time spent obtaining it.

Dr-Dd.........(ii)

4.4.2 Acceleration

The comprehensive ACC issue may be thought of as a mapping of distinct states to actions. The activity here is the host vehicle's acceleration. In order to protect the driver and passenger's safety, speed must be limited in regular driving speed ranges when scenarios like accidents or collisions occur.
ACC needs primarily two types of sensors.

1. Forward Scatter Radar will be used at the front of the vessels for sending and receiving waves to measure the distance of the front of nearby vessels or objects as well as their change in speed.
2. Monocular cameras will be placed in front and sides of vessels for object recognition.

As any metallic object can return any signals to radars which can be an issue for radars to measure distance accurately. For this reason, a camera is needed for the proper view of objects and to recognize them properly.

4.4.3 Feasibility

Though the ACC has already been implemented by many car brands like Toyota, Bosch, Hyundai, BMW, Tesla, etc. But the same principle can be implemented in vessels/ships to improvise the manual steering system. There can be a few limitations while implementing in vessels as the scenarios are a bit different, but if the scales can be brought up wide enough to the correct calibration, then it can be proven quite feasible and efficient.

4.5 Monitoring & Emergency Alarm System

For any advanced system, a proper monitoring and emergency alarm system is very crucial for safety and security. As for our advanced waterway transport system, we will have a fully secured emergency and real time monitoring system which will ensure full scale internal security and safety [12]. We propose few important features of monitoring and emergency alarm system. They are:

1. Engine Room
2. Fire Detection
   (a) Smoke Detection

(b) Temperature Detection

3. Fire Extinguisher

4. CCTV

1. **Engine Room :**
The monitoring system of the engine room will need CAN. CAN means Control Area Network. It is an electronic communication bus that defines how communication happens with internal devices in a very reliable way. We will need constant communication between these sensors to operate and generate data because we will be using many different types of active and passive sensors. The microcontroller and sensors will be connected through this CAN bus, where microcontrollers will be able to analyze data and execute monitoring of the vessels.

   The vessel's engine room consists of many types of heavy mechanical equipment, and many of them are subject to overheating and flammability. So, we need sensors that can autonomously detect these accidents from happening.

2. **Fire Detection:**

   (a) **Smoke Detection:** For smoke detection in engine rooms, MQ2 is a metal oxide semiconductor-based gas sensor. The sensor uses a voltage divider network to measure gas concentrations. This sensor is powered by a 5V DC source. It can detect gases with a concentration ranging from 200 to 10,000 parts per million. If there is any incident of fire or overheating in equipment in the engine room that results in smoke, the MQ-2 sensor will immediately detect it and send data to the microcontroller.

   (b) **Temperature Detection:** The DS18B20 is a temperature sensor that generates temperature data in 9 to 12 bits. These figures show the temperature of a particular device. This sensor may be communicated with via a one-wire bus protocol, which uses one data line to interact with the microcontroller. It is widely used in industrial systems.

   If the engine room in vessels catches fire as there are many flammable objects present there, then the DS18B20 temperature sensor will be able to detect it.

3. **Fire Extinguisher:**
When internal sensors detect fire incidents, the LCD screen on each deck will announce it and also a UI will be shown about the location of fire extinguishers.

Figure 4.6: Evacuation Map [21]

This evacuation map will be placed on the entry points of each floor indicating the position of the necessary emergency equipment placed. As throughout our field work, we have identified there was no such evacuation map available on the vessel/launches in our country.

4. **CCTV:**
For the internal security of the vessels, 24/7 CCTV coverage is one of the most important features. There will be a sufficient number of cameras placed on every deck, engine room, staff room, canteen, control room, captain's command deck.

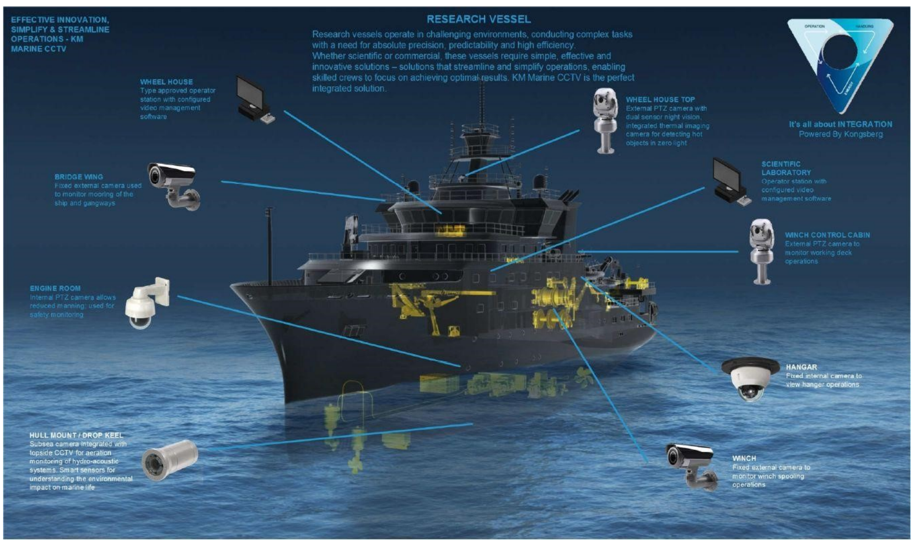

Figure 4.7: CCTV coverage [49]

On a vessel, there are many reports of theft, robbery, murder and other crimes. To solve this, internal security surveillance is a must.

There will be multiple screens in the control room from which all the CCTV will be monitored. The CCTV footage will be transmitted to the central control rooms for monitoring in our advanced waterway transport safety system based on the Internet of Things (IoT).

4.6 Location Configuration of Vessels

GPS can monitor the obstacles channel in real time and predict collisions, chasing, and also issue an alarm if something goes wrong by using GPS monitoring technology. This system takes data from the terminal device and stores and processes it as needed to meet the user's information query needs.

4.6.1 Database Design

GPS takes data on the terminal device and processes and stores it to suit the user's information query requirements [29].

1. **Electronic Chart Database:** Electronic charts, which are the most fundamental type of data, are available to be purchased from specialized database companies. A base layer is present in every database. Any and all other databases have to be put on top of the database of electronic charts.
2. **Ship Information Database :** Information about the ship includes its current location, speed, heading, geographic location and docking position, among other things.
3. **Video Database :** Information about a surveillance system in real time can include the number of cameras, the area being watched, the quality of the video being captured, etc.
4. **System Management Database :** The system management database is where the most important information is kept. This includes roles, permissions, logs, maintenance and changes to the storage system.

4.7 Encoding Methods

For data encoding and compression the RLE method can perform very effectively. This data is preserved in a value and a counter is applied rather than its previous form. RLE can be applied to graphical images, characters or in lines. But it is not efficient in files as they do not have many runs.

4.7.1 Data Encoding

In this system, we are using data encoding in 8 bits to represent it. This 8 bit data length will make it easier to store and send more data faster. Using 8 bit data, the maximum number of data that can be generated is $2^8 = 256$.

Information will be converted to 0s and 1s bits. In this IoT system, many sensors will be generating data and communicating among themselves. And this data has to be sent to the central control room for monitoring. But if all the data has to be sent in the raw form, then after merging it will be very long, the file size will increase. For this data file to be sent over and stored, the communication protocol (LoRa) we will use might slow down for massive data traffic and large data files. So, we have introduced data encoding for only the most important variables, such as weight calculation sensor data, ACC and sonar data, weather data and the overall vessel's internal sensors.

Bit patterns, often known as binary digits 0 and 1, are the means by which knowledge is stored. If each character were the same as the others, the alphabet would need to be represented using two bits for each character (a, e, r, and t). As a result, the sentence "A rat ate a tart at a tea" might be encoded using a total of 36 bits, which is the product of 2 times 18 bits. Assigning a variable-length binary code with "t" being the second most common character in this text will result in a flattened message consisting of only 32 bits. This is because "a" is the character that appears the most frequently in this particular text. The fact that no code can be used as a prefix to any other code is the defining characteristic of this encoding. Therefore, additional bits are not necessary to differentiate the letter codes; 010111 is unmistakably decoded as the letter A.

- First 2 bits represents accident status from ACC speed control and sonar data to detect whether collision occurred or not.
- Second 2 bits represents weather status.
- Third 2 bits represents Weight calculation data to detect overweight or not.
- Last 2 bits represents data from temperature ,smoke sensor to detect vessel's overall status is fine or not.

An encoded 8 bit data string is given at table below.

00	01	10	11
Accident	Weather	Overweight	Ok or Not Ok

Each 2 bit section will have $2^2 = 4$ combinations.

Bit String	Accident	Weather	Overweight	Overall Sensor Status
00	Not Accident	Weather sunny.	Vessel carrying optimal weight.	Sensors malfunction.
01	Accident	Weather cloudy/rainy.	Null	All sensor status fine.
10	Null	Weather stormy.	Vessel carrying overweight.	All sensors malfunction.
11	Null	Weather foggy.	Null	Null

Table 4.1: Our proposed data stream

Data:
1.52 pm: 00 01 10 11

Weight Calculation:
$Deck1 : 1200kg > 1100$
$Deck2 : 500kg < 700$

Ok or Not Ok == Overweight

4.8 Post-Accident System

The emergency system examines and analyzes the data received from the control unit using various data algorithms (e.g., data fusion algorithms) . Data may be retrieved from cloud services over the internet at any time. After evaluating the data, to commence contact with the vehicle and rescue operation, the application service sends an alarm to the authorities, unit, and station terminal, as well as the nearest rescue station. This includes the ship's serial number, location and any other pertinent information [8].

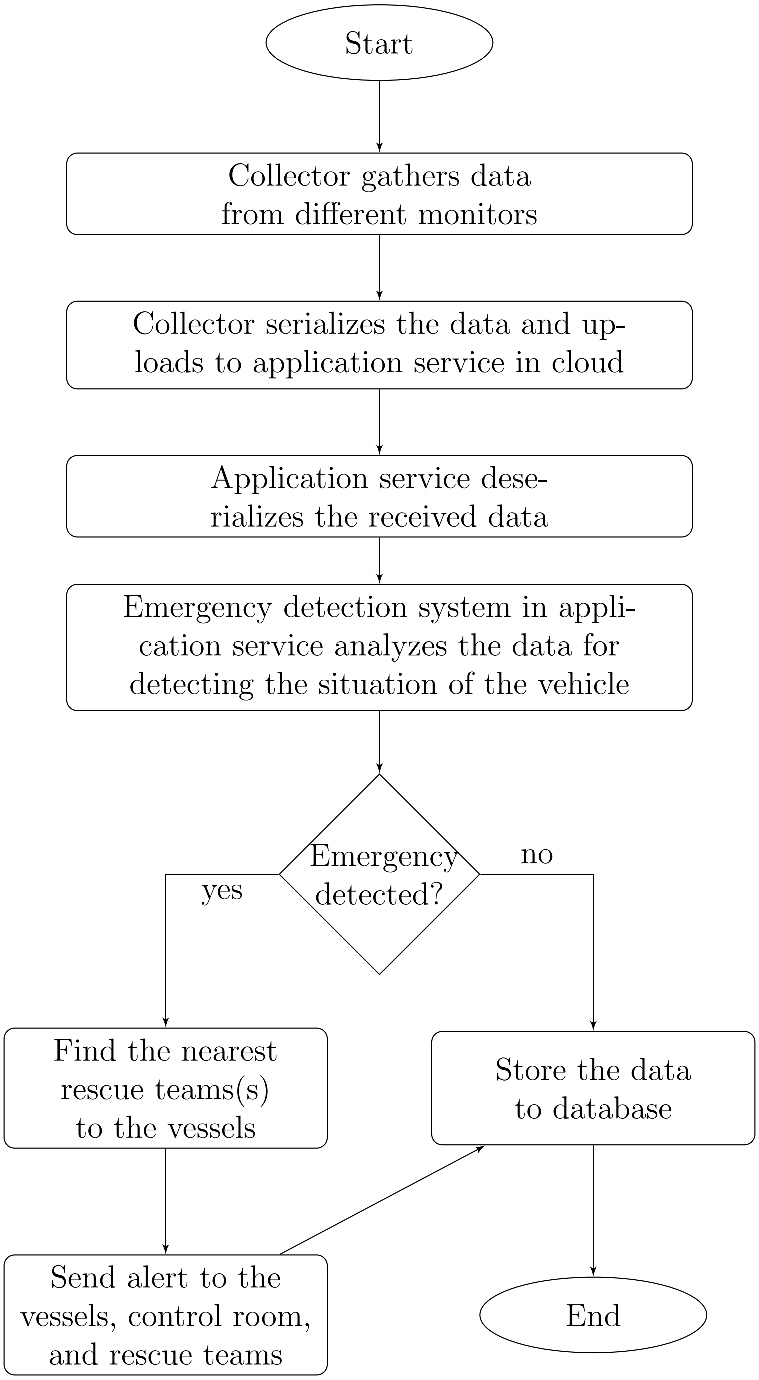

Figure 4.8: Post Accident Methodology

Using sensor data supplied from the operating vehicle's control unit to forecast crises and odd occurrences. The first stage's technique encoded fundamental features such as the report's unique id (Unique Id), the accident kind (Accident Type) and the vessel's name (Vessel Name).

The date of the disaster (Date), the length of the vessel (Vessel Length) and the kind of vessel (Vessel Type).

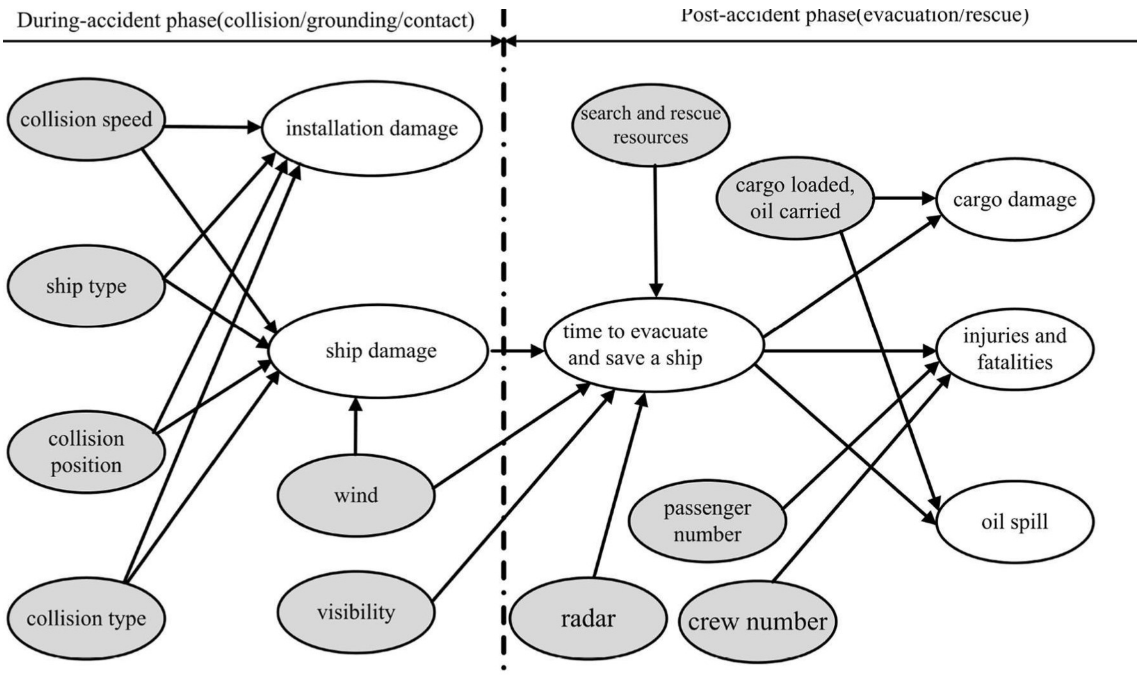

Figure 4.9: Post accident flow chart

Vessel Name	Serial no	Accident type	Person on board	Vessel Type	length	Date
Kuakata	Bar1104	Contact	8	Passenger vessel	78.7 and 55.50	March 7, 2019

Table 4.2: Data collection of Vessel

4.8.1 Data Collection

Attributes	Categories	Type	Unit
Unique ID	Serial Number	Numeric	
Date		DD/MM/YYYY	
Ship	Length Vessel Type Name	Numeric String String	Meters
Location		String	
Accident Type		String	

Table 4.3: Data collection format

This procedure might contribute to the emergence of new, more effective emergency management solutions dataset of ship information. A C# language application has built to detect emergency events from the dataset. The software is hosted on the VPS and data is sent via a shared broadband internet connection of 4 mbps over HTTP from a client PC to the application. When the ship encountered any form of disaster or incident, the server program will evaluate the data and create an emergency warning. As a result, whenever the ship has a problem or an accident, the program begins delivering emergency warnings through the control room and the nearest rescue workers are notified through GPRS. In the Figure 4.10, it shows that Kuakata Express was involved in an accident, prompting the server application to issue an emergency notice.

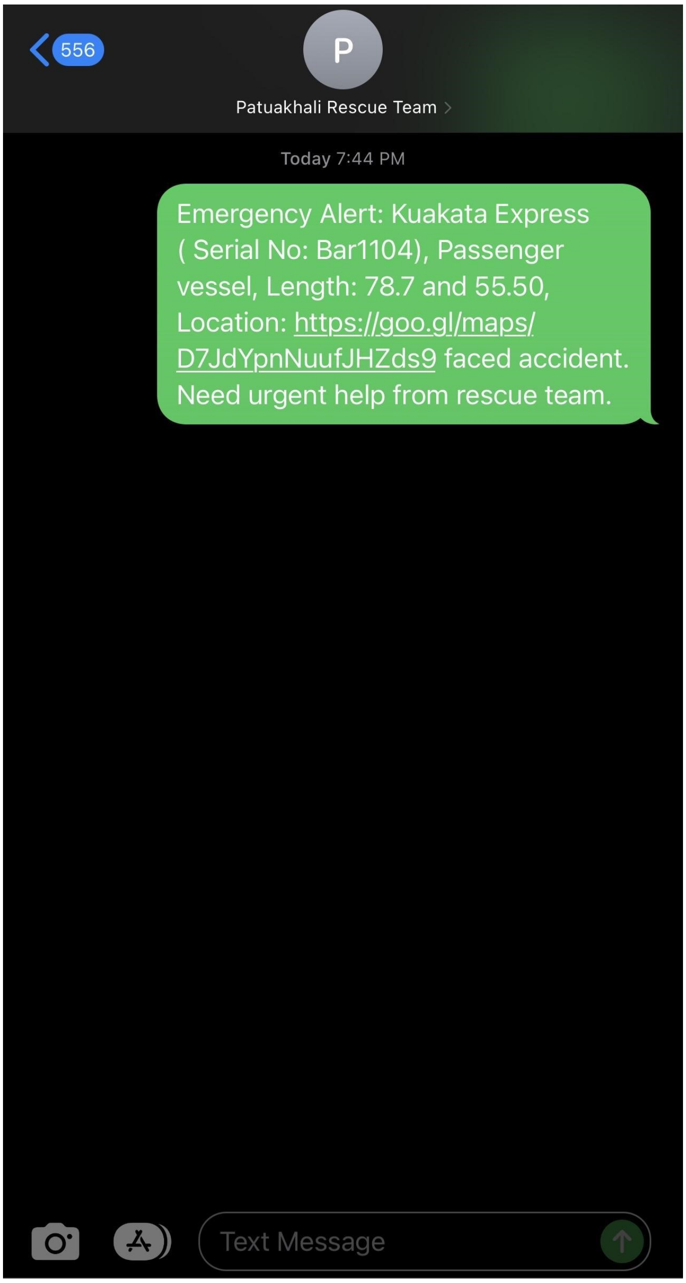

Figure 4.10: Sending Emergency message to rescue team

4.9 Central Control Room Operation

The task of the monitor in the control room is to show data on the vehicles in motion, such as their location, estimated weight and any precautions taken to ensure their safety. This system will use the Internet of Things (IoT) to upload data gathered from moving vehicle monitors.

We store information on the server so it may be viewed on the control room monitor [12]. Using an internet-based audio-voice communication system, operators in command centers will be able to talk to drivers in moving vehicles in case of an emergency.

The Web page display module and the data collection transfer module are the two main components of the server data visualization terminal. There are two components that make up the page display module: the data display page and the JavaScript script. The term "ships' data display page" refers to the medium used to present data on vessels (ship location, weather info, weight load, sonar information and distance between ship and nearest ship). Flexible data collection and presentation are enabled through a JavaScript script that links the ship data display page to the Google Maps API interface [46]. With the help of the data collection transfer, we can link the database module to the ship data display page and send over any and all data pertaining to the fleet [24]. During the transfer process, the JS script calculates and processes all of this information and the final results are then sent to the Web page that is being shown [5].

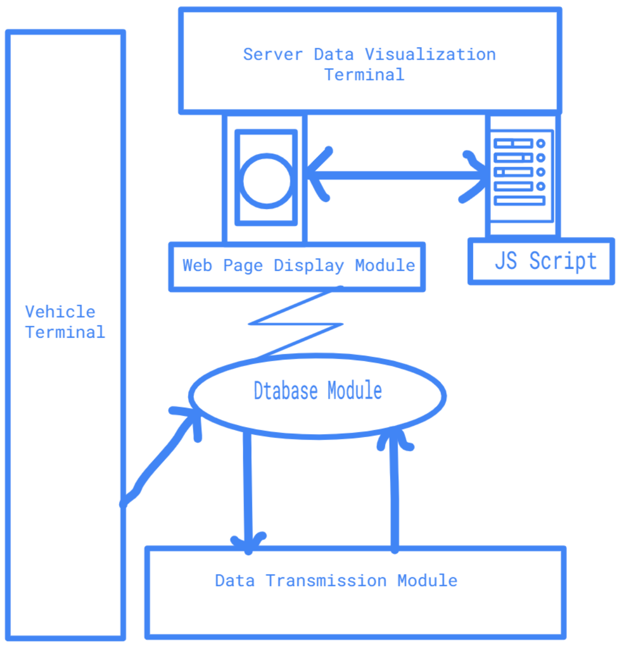

Figure 4.11: Software frame

The control room monitor will display this map animation where the location mark indicates a ship. Every mark on the ship will remain one particular color. When the moving ship faces any emergency situation, according to our generating data then the mark of the ship will be red and lead to a short alarm for the person who will be in charge of the control room. Then the person in charge will open the red-marked ship web page by clicking on the mark to see the safety information and take his step as there will be VHF for voice communication with the coast guard and nearest ship.

Figure 4.12: Map Animation of monitor display.
Note: White area contain the waterway where location mark indicate a ship

Chapter 5

Experimental Evaluation

5.1 Experimental Testbed Setup

In this paper, we have proposed an Advance Waterway Transport Safety System, based on Internet of Things (IoT) architecture where different types of a number of sensors, modules and micro-processor will be used. As a prototype of the implementation work the data transfer process is considered to be one the most crucial and significant part.

Both data collection through the active and passive sensors and transferring it over wireless data communication is necessary. As, we have to extract the relevant information from the datasets of each sensor. The data collection and transmission have to be fast, secure and concurrent.

As a matter of fact, we are working with real-time data so the update of the concurrent data has to be transferred over a specific time lapse to avoid any fatality from happening.

For a prototype of the data collection and data transfer of the microprocessor, we are using is Arduino Uno. For sensors we have used:

- Ultrasonic Sonar Sensor HC- SR04
- DHT11–Temperature Sensor
- Humidity Sensor
- LM393 Speed Sensor
- Smoke Sensor

Data communication module:

- ESP8266 Wi-Fi MCU
- LoRa

Block Diagram of Full Set Up:

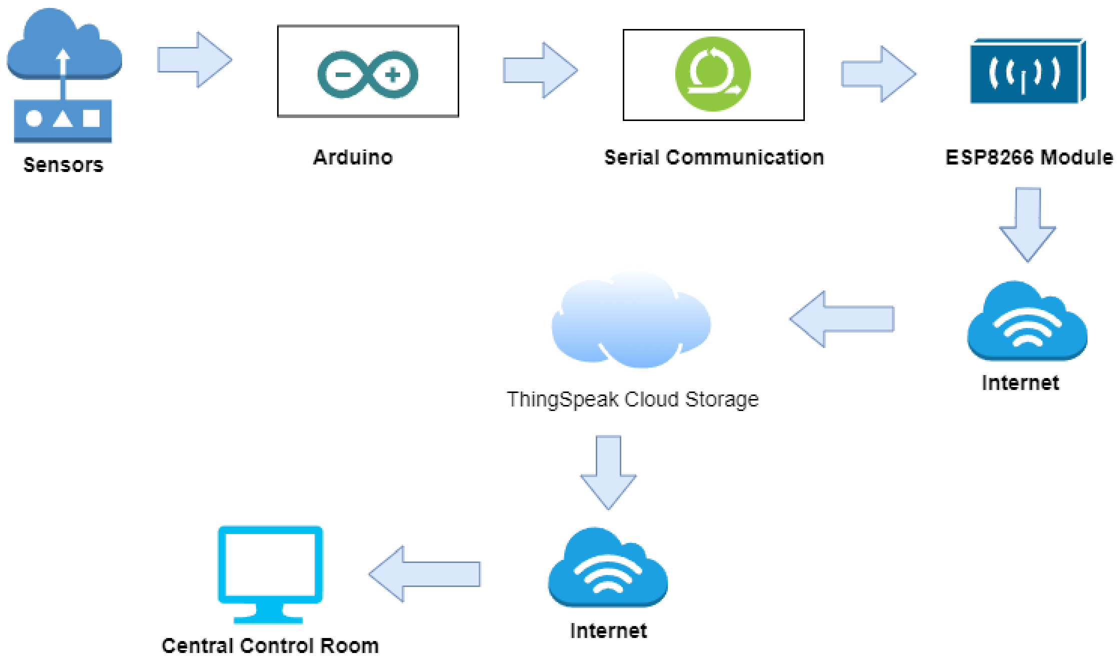

Figure 5.1: Overall Full Communication Setup

In figure 5.1 we have shown the block diagram of sending ultrasonic sonar sensor data to Cloud server (ThingSpeak). Firstly, the Arduino will trigger the ultrasonic sensor,temperature,smoke and humidity sensor after calculating it, the Arduino will send sensor data. Finally, ESP8266 will send this data to your ThingSpeak account through the internet to the Cloud server.

Circuit Diagram:

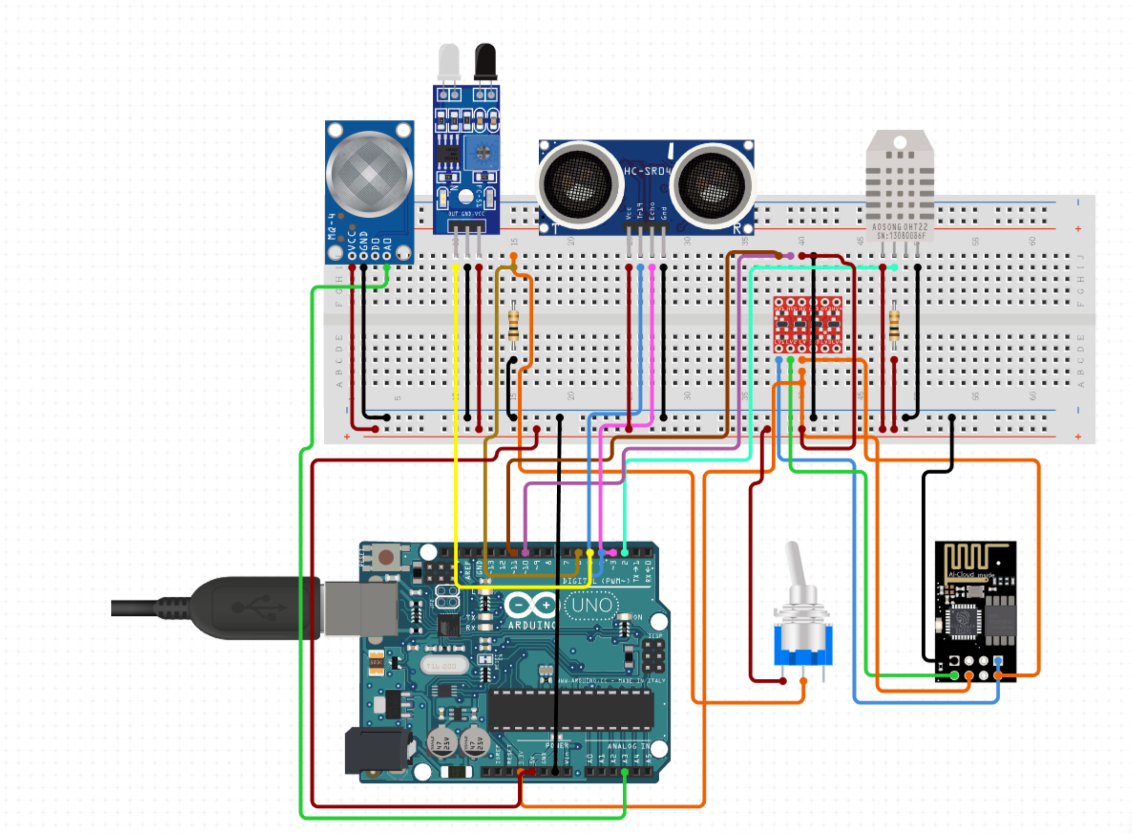

Figure 5.2: Circuit Diagram of Prototype

5.2 Experimental Result

We describe the experimental result by our contributions separately.

1. **Weight Detection Accuracy:**
   Our proposed weight detection method is much more accurate than any other pre-built method to detect the weight of a multiple entrance passenger carrying ship.From our implemented camera load line, the sign of the ship is going to the image processing method which we implemented in the control room monitor. After that our trained algorithm data set makes a decision by comparing the load line sign that it is overloaded or not. In the Table (8.1), shows that our image processing algorithm is detecting all the signs correctly which means this model is 100 percent accurate to detect all types of signs. This weight detection model gives us the exact result that the ship is overloaded or not. As this model checks the loadline sign of a ship, multiple entrances of a ship cannot take extra weight which will not be countable in our calculated method. So if the ship is overloaded, then it will be notified to the control room and the ship will not start its journey. Because, an overloaded ship can make an accident in its journey. So when it is ready with accurate weight only then it can start its journey.

	Sign dataset	Accuracy
Test images	12	100%
Sign(100%) under water	2	100%
Sign(>50%) under water	4	100%
Sign(100%) above water	6	100%

Table 5.1: Detection Accuracy

2. **Collision Ignoring Accuracy:** Our setup sonar model is able to detect 360 degree object detection. Sonar sensor detecting object distance and this distance is transferred to the web server by using arduino and esp8266 wifi module. After detecting an object in clouser range, sonar informs the captain that something is in front of us which can cause a collision. This detection of distance is 96 percent accurate which can lead the ship to a correct direction.

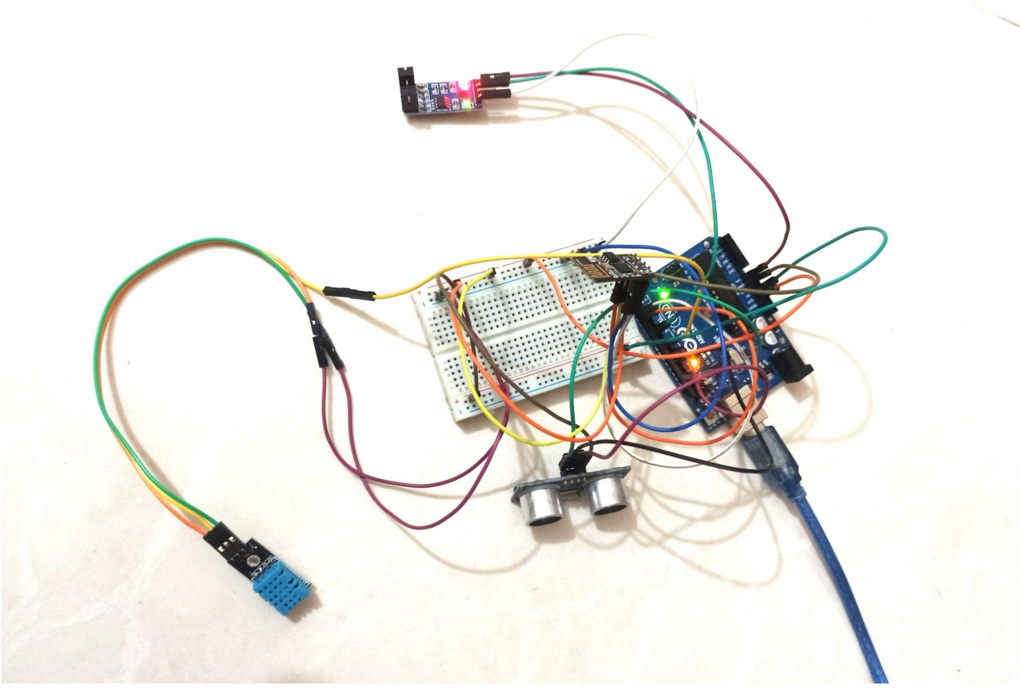

Figure 5.3: Object, Temperature-Humidity, Speed Detection and ESP8266 module using Arduino

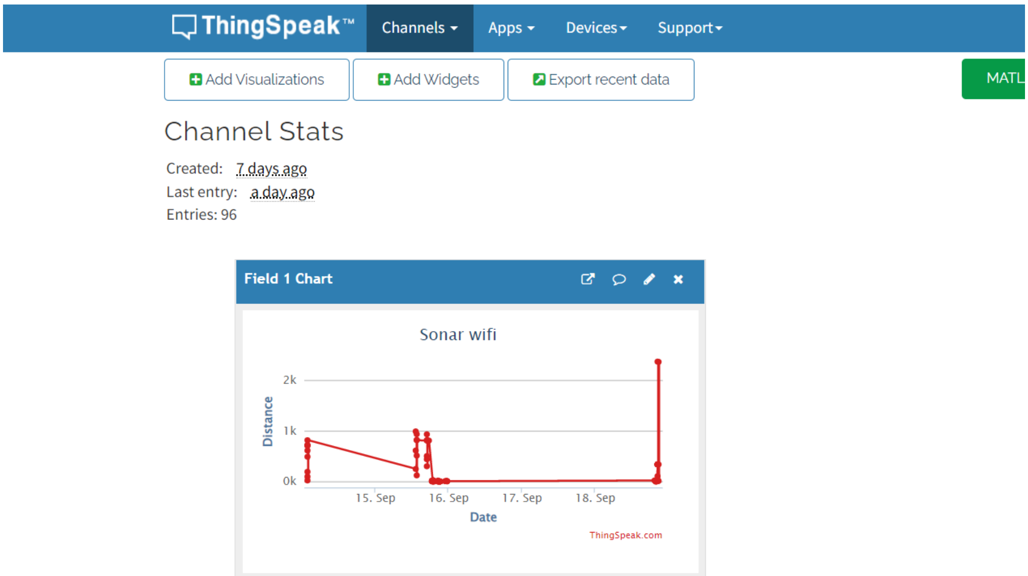

Figure 5.4: Sonar Data Transfer and Visualization on Cloud Storage

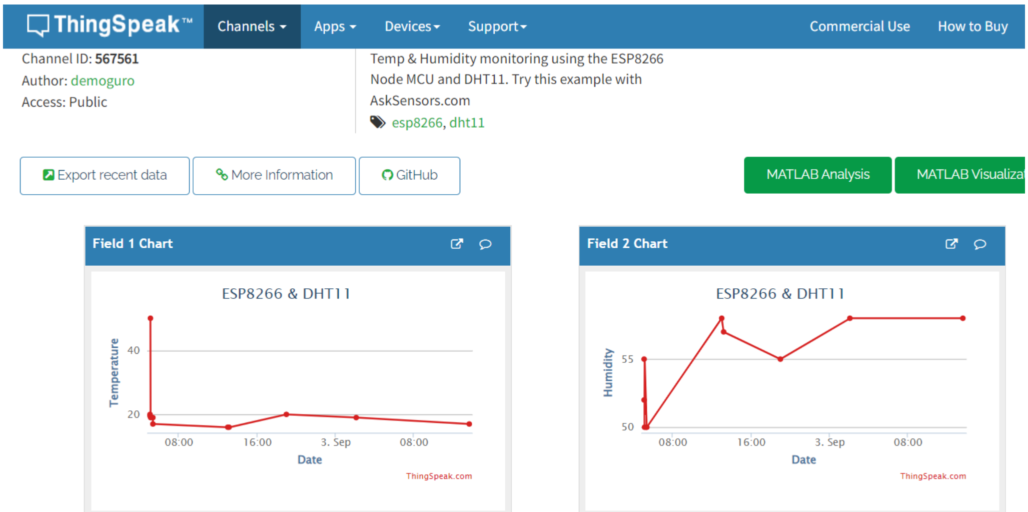

Figure 5.5: Temperature and Humidity Data Transfer and Visualization on Cloud Storage

In figure 5.4 and 5.5 we have shown the multiple sensor data collection from our prototype and transferred it through the internet. The data is finally visualized on the cloud storage.

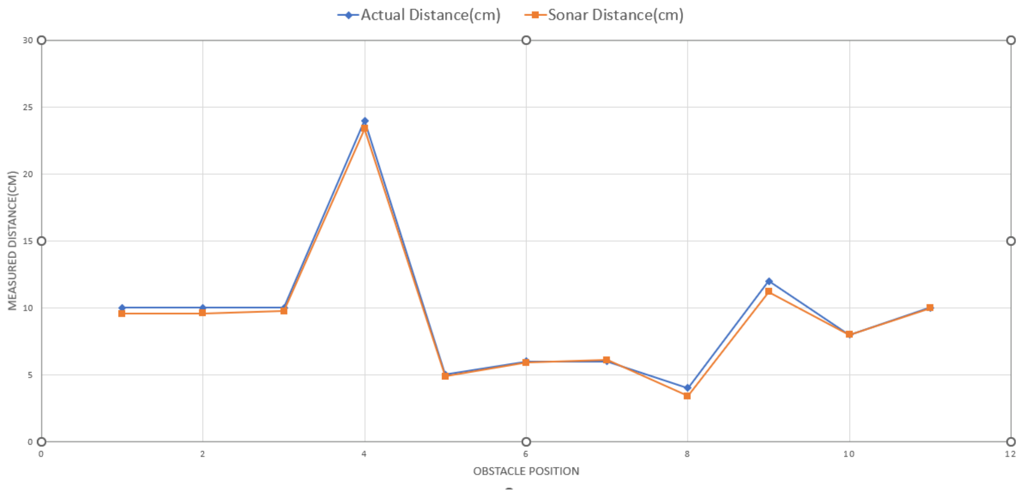

Figure 5.6: Measured Distance (cm) vs Obstacle Position Graph

In figure 5.6, we have shown the data plotted graph of actual and Sonar calculated distance. The graph shows the plot of the dataset collected using ultrasonic sonar sensor. These data were fetched from the cloud storage where all sensor data were stored. Later, we compared our measured distance to determine graph and accuracy. Finally, here Measured Distance (cm) vs Obstacle Position data the accuracy is 96.20%.

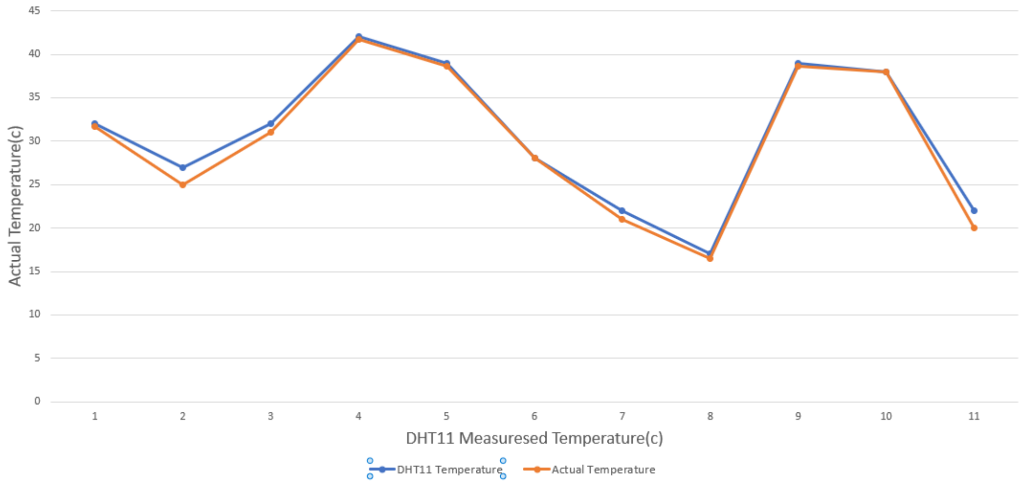

Figure 5.7: Actual temperature (c) vs DHT11 Measured Temperature(c) Graph

In figure 5.7 the plot graph of Actual temperature (c) and DHT11 Measured Temperature (c). DHT11 Measured Temperature data was collected from cloud storage and shown comparison. Finally, here Actual temperature (c) vs DHT11 Measured Temperature(c) data accuracy is found 93%.

3. **Speed Control Accuracy:** By using Adaptive Cruise Control (ACC) we are handling a safe and sound distance from our surroundings. In this system distance will be calculated automatically. We will set a threshold distance which will be used to compare with automatically calculated distance for making decisions that speed needs to be controlled or not. When a target vessel is

near to the host vessel, it will check whether we can pass this vessel or not. If it is able to maintain the speed to pass that vessel avoiding collision then it will be ignored by our speed control otherwise our architecture intervenes as an overdrive of the manual control of the vessel whether the captain is aware or not.

5.3 Experimental Findings And Comparative Analysis

5.3.1 Experimental Findings

1. **Weight Detection:**
   We approach to find an optimal solution to detect overloading problems. For multiple entrances of a ship we can not detect an accurate weight by calculating their weight one by one.But we had to make a statement for overload or not. In solving this problem we are getting an accurate detection of overloading or not. Our proposed weight calculation method, where image processing detects ships load line to define overload. Firstly we are getting images on our camera which are getting checked by our trained sign in image processing method. After that we are getting our binary decision for overloading or not.

2. **Collision Avoidance:**
   We are detecting obstacles on a continuous basis by using sonar sensors. This sensor is 360 degree surrounding our ships where any obstacle like other vehicles or any other things will be detected by this sensor. To keep track of the correct path, the captain can easily depend on our finding distance of obstacles.The distance will be saved in a spreadsheet everytime which can be used for further need.Along With this our sonar sensor value is also visible in the web server by which we are avoiding all the obstacle for avoiding collisions with other vehicle and things.

3. **Speed control to avoid collision:**
   Sometimes the captain of a ship can not understand that his ship can pass or not the vehicle in front of him which can make a collision. Here our proposed implemented system automatically calculated the speed of our and other vehicle speed and made a calculation that speed needed to slow or fast to avoid collision. After that this system automatically speeds up in a way so that our ship can maintain a sound and safe distance from other vehicles.

5.3.2 Comparative Analysis

It reviews some papers related to weight calculation accuracy, communication protocols and comparison of different architectures. Based on those papers main focusing points, we gave our overviews to bring a conclusion to choose components according to our needs and fits perfectly in these circumstances.

5.3.2.1 Weight Calculation

Problem of overloading is the major issue for accident. We have tried to figure out some weight calculation techniques and compare them with our approach.

Papers	Weight calculation technique	Accuracy	Comparison
Mohaimenuzzaman et al. [21]	A separate directional sensor that is mounted in the door of the vehicle and used to count people or check the load level.	Undefined	Since the sensor is at the entrance only, this system will not be feasible for our country. Because people enter the vehicle without a certain entrance like a window.
Z. Yongjun et al. [13]	RFID readers are utilized to count the number of passengers boarding and disembarking a vehicle. However, given that every passenger must have a card with an RFID tag at this time.	Undefined	It may be a challenging assignment for a developing nation like Bangladesh. Because, it is not possible to have an RFID tag on every passenger.
Malcolmson et al. [7]	It shows the mass by getting the water level up.	As the accuracy of its different method is based on age it is undefined.	Since accuracy is not defined for combined ages it can be hard to find the correct weight of passenger vessels.
Our approach	Through image processing of the load line we can detect overload.	The detection accuracy is close to 91%, while classification accuracy is greater than 98% [24].	

Table 5.2: Comparison of weight calculation technique

5.3.2.2 Communication Protocol

There are many communication protocols available like Zigbee [17], Bluetooth [26], SigFox [38] etc. Among them we chose the LoRa communication protocol due to its long range, low power consumption and low cost connectivity. Also, it is efficient for logistics or moving objects from a long distance. The reason is to choose LoRa, we made a comparative analysis among various paper based on different communication protocols:

Paper/Content (Year)	Focusing points	Module	Our review
Aju et al.[17] (2015)	This paper has talked about the basics of ZigBee sensor networking technology, such as its interoperability protocol, open standard, low cost, low speed, and low power consumption.	Zigbee	Low complexity, short range, low data speed, and incompatible with distant moving objects.
Hortelano et al.[26] (2017)	This paper proposed a packet format and two (Individual Mesh and Collaborative Mesh) topologies by using Bluetooth to improve its performance.	Bluetooth	Low cost and simple design implemented by changing topologies to improve speed but range is very short.
Hadidi et al.[25] (2017)	In this paper, a model was proposed using various protocols together to optimize network traffic and eliminate conflicts.	Multiple module	Complex design and costly.
Purnama et al.[38] (2020)	This paper proposed SigFox protocol based on radio configuration with various frequencies.	SigFox	High power consumption, costly and long range.

Our approach (2022)	We propose the LoRa communication protocol for our sensor data transmission for its autonomous network without any third-party attachment with simple design, while fulfilling low power consumption and long range communication.	Lora	Low power consumption, high speed, simple design, long rang and compatible with distant moving objects.

Table 5.3: Comparison of communication protocols

5.3.2.3 Comparative Study of Our Proposed Model

Name	Weight Calculation	Obstacle Detection	Data Encoding	Weather Forecasting	Speed Distance Control	Tracking
Mohaimenuzzaman et al. [22]	Yes	No	No	No	No	GPS
A. Ullah et al. [42]	Yes	Yes	No	Yes	No	GPS
H. Deng et al. [30]	No	No	No	No	No	GPS
D. Chen et al. [17]	No	Yes	No	No	Yes	GPS
Ahmed et al. [36]	No	Yes	No	No	No	GPS
Juan et al. [47]	No	Yes	Yes	No	No	No
Chen et al. [37]	Yes	No	No	No	Yes	GPS
Zunair et al. [32]	Yes	Yes	No	No	No	GP
Our Proposed Approach	Yes	Yes	Yes	Yes	Yes	GPS

Table 5.4: Comparison of Our Proposed Approach with Other Existing Research Studies

In Table 5.4, comparison of our proposed model with other research papers.

Chapter 6

Discussion

6.1 Initial Development and Models

In a densely populated developing country like Bangladesh, the river plays a very significant role in terms of regional transportation, communication and connectivity. According to the Bangladesh Inland Water Transport Authority (BIWTA), around 80 million passengers use inland waterway transportation each year. So, it shows how important this sector is for the communication and transport of Bangladesh. Throughout our research, we have used various models and technologies to recognize the problem and offer a feasible and effective solution to ensure the safety of the vessel's passengers. In the initial development, we are in need of real-life data and we have to point out the real-time problems that are present at the time. So, to address and understand the problem properly, we collected real-time data.

6.2 Field Work

For real-life data collection research, we conducted field work on several vessels/launches at Dhaka SadarGhat Launch Terminal, the busiest and largest inland waterway launch terminal in Bangladesh.

Figure 6.1: Field work to collect information

Passenger Capacity	640
Life Jacket	68
Floating Wheel	70
Fire Extinguisher	18
Safety Torch	1
Radio	1
CCTV	8
Sonar/Sensor	0

Table 6.1: Equipments found on MV Mitali-7

The figures for the equipment mentioned in table 6.1 were found during the survey on MV Mitali-7 Launch (Chandpur), but the official numbers of those given by the vessel authorities surely conflict. In comparison to the vessel's passenger capacity, the number of emergency equipment's on board is far from adequate. Other than that, the number of passengers exceeds much more than the capacity during national holiday this reflects the poor manual monitoring conditions that lead to frequent fatalities happening in inland water transportation.

Figure 6.2: Scenario of deck

Our advanced waterway transport safety system offers the use of various sensors to monitor the number of equipment present in the vessels and data monitored by the central control room. This external monitoring will prompt authorities to ensure an adequate supply of safety equipment. During the voyage from Dhaka to Chandpur, the distance is around 115 km(By River).During this journey, they mentioned about 4 Bangladesh River Police checkpoints.

1	Pagla
2	Munshiganj
3	Gojaria
4	Chandpur

Table 6.2: Bangladesh river police checkpoints

This data shows that during this almost three-hour voyage, if any incident, accident, or fatality happens, there will be only four nearest possible locations from where the vessel will be able to get assistance from authorities.

For the vessel's weight estimation, as per the captain's statement, the vessel has a load line mark on the submerged frontal side of every vessel. A load line, also called a Plimsoll mark, is a marking indicating the extent to which the weight of a load may safely submerge a ship by way of a waterline limit. Using this manual technique to check the mark manually, a rough calculation is done of the overweight on the vessel. But this manual technique can be miscalculated or erroneous, and it can be ignored even after an overweight indication.

Figure 6.3: Load line image

Furthermore, the data will be sent to the central control room for monitoring. The field work shows there has been no use of sensors in the vessels/launches. Sonar is not used to find nearby ships either in the engine room or on the control deck.

From the statistics we have found that one of the major reasons for collisions in inland waterway transportation vessels is the lack of adequate control over the speed and distance maintained by the vessels' captains while steering.

According to our survey, most of the accidents involving collisions have been the result of manual reckless steering. So, to solve this issue, we have to have control over the speed and distance maintained by vessels while on voyage.

6.3 Limitation

In our proposal, there are some limitations we found and they are:

1. As a densely populated country like Bangladesh, there is no single point entry in the vessel/launch. As a result, people sometimes illegally enter into the moving ship from sides (windows, sideways, side doors) by other boats which causes some slight miscalculation to the weight calculation that is done prior to ship departure from dock.

2. There was very few survey or statistics about ship facilities for inland waterways transportation in Bangladesh. Consequently, we had to go to field work to collect data and information about ship operations and functionality to find out the root causes of accidents. Our survey was based on Dhaka to Barisal/Chandpur roots. So, we do not know if there are any other issues in the other roots that cause accidents. Our paper deals with the busiest inland route (Dhaka to Barisal) issues.

3. We could not implement ACC due to lack of funds and resources.

6.4 Insufficiency of Resources

Now the Internet of Things (IoT) is gaining popularity as a hot topic technology. Bringing physical objects to the internet is a great concept. It is also growing in popularity in teaching and research. About the growth of IoT products, many suppliers and manufacturers comment on what the future will look like to develop in this area. Many kinds of lightweight protocols have been developed to establish communication between different physical objects. But in the absence undefined information makes it difficult to provide accurate and error-free information. Thus, the correct information is such a problem. It needs to be addressed to turn speculation into reality. There is a lot of information. We found it confusing and also thought the information was not good enough for research-

1. Many IoT systems today are minimally written and implemented on the Internet, using a variety of protocols and technologies to confuse and create complex configurations.

2. There is not much research about this topic. So, for that, the information we got was insufficient.

3. The data analysis is not found properly on the internet. For this, it is difficult to know different information and procedures about data analysis.

4. Insufficient survey on root cause of ship accidents in Bangladesh.

5. There is not enough instruction about IoT device maintenance and management.

6. No previous work was done in our inland water transportation safety.

7. Due to lack of funds and resources for sensors and new technologies in Bangladesh.

6.5 Cost:

LoRa radio module, Adapter Plate, Coil Antenna.
Total cost = 8.05 $
HopeRF RFM95 868MHz
2 pieces(22.00 $)
ESP 8266 wifi adapter plate +2 pin header
1 piece (10 $)
Copper Wire
Diameter 1mm, Length 1m
1 piece (0.90 $)
Uno Arduino, Breadboard, Jumper wires, Pin Header
Total cost= 10.56 $

Adaptive Cruise Control (ACC) is a smart cruise control that automatically adjusts the speed, brakes, and control speeds to maintain a safe distance between vehicles in order to avoid collisions. The model uses radar, a monocular camera, and a processing unit. Marine Radar costs around 2000-2500 $, monocular cameras cost around 1500-2000 $, which totals around 4500 $.

Chapter 7

Future Work and Conclusion

7.1 Future Work

In the first phase, we developed an IoT-based safe waterway transportation system. In addition to this work, we want to add something more in the near future. For the moment, all we have is a safe transportation system for a safe journey through the waterway. However, we aim to add an advanced docking system to it to improve the docking system. Our docking system will include a slot system so that it will always remain stable for docking. For example, in our country, big and small ships dock together without any proper placement in port. To reduce these risks, we will use a sensor per slot in the station to detect if the slot is empty or occupied. We will also build an algorithm for an automated ship assigning system so that the system will assign ships a particular slot according to their size to a particular slot to dock. For these implementations, we need more manpower, more time, and more money, which we lack now. We are hopeful to achieve the above-mentioned improvements in the near future.

7.2 Conclusion

The present waterway transportation in our country is inadequate in terms of safety. The water transportation system in Bangladesh is very crucial and sometimes disastrous due to a lack of a compatible ship management system. A ship management system such as this is to minimize the risk of accidents caused by mismanagement of ships in waterways. The goal of this article is to create a safe water transportation system with the assistance of a central control room by analyzing data collected from sensors and built-in systems by using IoT. The sensor data transmission is done by a Wireless Sensor Network (WSN) for better communication using a LoRa module and LPWAN. The system will be able to provide unimpeded ship movement without any collisions due to advanced technology. Additionally, will ensure smooth and risk-free waterway transportation. We have demonstrated a primary depiction of a ship/vessel management system enhancing safety and security.

Bibliography

[1] A. Springer, W. Gugler, M. Huemer, L. Reindl, C. Ruppel, and R. Weigel, "Spread spectrum communications using chirp signals," May 2000, pp. 166–170, ISBN: 0-7803-6323-X. DOI: 10.1109/EURCOM.2000.874794.

[2] J. T. Bather and D. Fusion, "Iee international seminar target tracking: Algorithms and applications," in *IEE Target Tracking: Algorithms and Applications (Ref. No. 2001/174)*, vol. Seminar, 2001, 0_1–0_7.

[3] G. Marsden, M. Mcdonald, and M. Brackstone, "Towards an understanding of adaptive cruise control," *Transportation Research Part C: Emerging Technologies*, vol. 9, pp. 33–51, Feb. 2001. DOI: 10.1016/S0968-090X(00)00022-X.

[4] Z. I. Awal, M. Islam, and M. Hoque, "Analysis of passenger vessel accidents in the inland waterways of bangladesh," Sep. 2006.

[5] P. Bradwell and S. Marr, *Making the most of collaboration : An international survey of public service co-design (demos report 23)*, 2008. [Online]. Available: https://lx.iriss.org.uk/content/making-most-collaboration-international-survey-public-service-co-design-demos-report-23.

[6] N. Chadil, A. Russameesawang, and P. Keeratiwintakorn, "Real-time tracking management system using gps, gprs and google earth," in *2008 5th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology*, vol. 1, 2008, pp. 393–396. DOI: 10.1109/ECTICON.2008.4600454.

[7] M. Malcolmson, D. Sacco, and T. Whiting, *Passenger vessel weight measurement*, 2008. [Online]. Available: https://web.wpi.edu/Pubs/E-project/Available/E-project-121908-113518/unrestricted/Passenger_Vessel_Weight_Measurement.pdf.

[8] E. Tzannatos and D. Kokotos, "Analysis of accidents in greek shipping during the pre- and post-ism period," *Marine Policy*, vol. 33, pp. 679–684, Jul. 2009. DOI: 10.1016/j.marpol.2009.01.006.

[9] M. Ainslie, "Principles of sonar performance modelling," 2010. DOI: 10.1007/978-3-540-87662-5.

[10] A. Amin, H. A. Qureshi, M. Junaid, M. Y. Habib, and W. Anjum, "Modified run length encoding scheme with introduction of bit stuffing for efficient data compression," in *2011 International Conference for Internet Technology and Secured Transactions*, 2011, pp. 668–672.

[11] F. Ahmed and S. Udas, *Dozens missing after ferry capsizes in bangladesh*, 2012. [Online]. Available: https://edition.cnn.com/2012/03/13/world/asia/bangladesh-ferry-sinking/index.html.

[12] Y. Wang and H. Qi, "Research of intelligent transportation system based on the internet of things frame," *Wireless Engineering and Technology*, vol. 03, Jan. 2012. DOI: 10.4236/wet.2012.33023.

[13] Z. Yongjun, Z. Xueli, Z. Shuxian, and G. shenghui, "Intelligent transportation system based on internet of things," in *World Automation Congress 2012*, 2012, pp. 1–3.

[14] *Bangladesh ferry sinking kills 14, five still missing*, 2013. [Online]. Available: https://www.reuters.com/article/us-bangladesh-ferry-idUSBRE91801V20130209.

[15] L. Xie, J. Chen, Z. Yan, and Z. Wang, "A new method of inland river overloaded ship identification using digital image processing," *Lecture Notes in Electrical Engineering*, vol. 220, pp. 499–506, Jan. 2013. DOI: 10.1007/978-1-4471-4844-9_67.

[16] E. Bondi, L. Seidenari, A. D. Bagdanov, and A. Del Bimbo, "Real-time people counting from depth imagery of crowded environments," in *2014 11th IEEE International Conference on Advanced Video and Signal Based Surveillance (AVSS)*, 2014, pp. 337–342. DOI: 10.1109/AVSS.2014.6918691.

[17] O. G., "A survey of zigbee wireless sensor network technology: Topology, applications and challenges," *International Journal of Computer Applications*, vol. 130, pp. 47–55, Nov. 2015. DOI: 10.5120/ijca2015907130.

[18] *Scores killed in bangladesh ferry accident*, 2015. [Online]. Available: https://www.aljazeera.com/news/2015/2/23/scores-killed-in-bangladesh-ferry-accident.

[19] S. Amabdiyil, D. Thomas, and V. Pillai, "Marine vessel detection comparing gprs and satellite images for security applications," in *2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, 2016, pp. 1082–1086. DOI: 10.1109/WiSPNET.2016.7566303.

[20] A. Augustin, J. Yi, T. Clausen, and W. M. Townsley, "A study of lora: Long range amp; low power networks for the internet of things," *Sensors*, vol. 16, no. 9, 2016, ISSN: 1424-8220. DOI: 10.3390/s16091466. [Online]. Available: https://www.mdpi.com/1424-8220/16/9/1466.

[21] M. Mohaimenuzzaman, S. Rahman, M. Alhussein, G. Muhammad, and K. Mamun, "Enhancing safety in water transport system based on internet of things for developing countries," *International Journal of Distributed Sensor Networks*, vol. 2016, pp. 1–10, Feb. 2016. DOI: 10.1155/2016/2834616.

[22] B. Reynders, W. Meert, and S. Pollin, "Range and coexistence analysis of long range unlicensed communication," in *2016 23rd International Conference on Telecommunications (ICT)*, 2016, pp. 1–6. DOI: 10.1109/ICT.2016.7500415.

[23] S. Sakib and M. S. Bin Abdullah, "Gps-gsm based inland vessel tracking system for automatic emergency detection and position notification," in *2016 10th International Conference on Intelligent Systems and Control (ISCO)*, 2016, pp. 1–4. DOI: 10.1109/ISCO.2016.7727018.

[24] S. Ardianto, C.-J. Chen, and H.-M. Hang, "Real-time traffic sign recognition using color segmentation and svm," May 2017, pp. 1–5. DOI: 10.1109/IWSSIP.2017.7965570.

[25] M. Hadidi, J. Al Azzeh, O. Tkalich, R. Odarchenko, S. Gnatyuk, and Y. Khokhlachova, “Zigbee, bluetooth and wi-fi complex wireless networks performance increasing,” *International Journal on Communications Antenna and Propagation (IRECAP)*, vol. 7, p. 48, Feb. 2017. DOI: 10.15866/irecap.v7i1.10911.

[26] D. Hortelano, T. Olivares, M. C. Ruiz, C. Garrido-Hidalgo, and V. López, “From sensor networks to internet of things. bluetooth low energy, a standard for this evolution,” *Sensors*, vol. 17, no. 2, 2017, ISSN: 1424-8220. DOI: 10.3390/s17020372. [Online]. Available: https://www.mdpi.com/1424-8220/17/2/372.

[27] U. Noreen, A. Bounceur, and L. Clavier, “A study of lora low power and wide area network technology,” May 2017, pp. 1–6. DOI: 10.1109/ATSIP.2017.8075570.

[28] U. Raza, P. Kulkarni, and M. Sooriyabandara, “Low power wide area networks: An overview,” *IEEE Communications Surveys Tutorials*, vol. 19, no. 2, pp. 855–873, 2017. DOI: 10.1109/COMST.2017.2652320.

[29] H. Deng, R. Wang, K. Miao, Y. Zhao, J. Sun, and J. Du, “Design and implementation of ship gps monitoring and dispatching system for intelligent transportation system,” *Proceedings of the International Conference on Information Technology and Electrical Engineering 2018*, 2018. DOI: 10.1145/3148453.3306261.

[30] Y. Hanada, L. Hsiao, and P. Levis, “Smart contracts for machine-to-machine communication: Possibilities and limitations,” in *2018 IEEE International Conference on Internet of Things and Intelligence System (IOTAIS)*, 2018, pp. 130–136. DOI: 10.1109/IOTAIS.2018.8600854.

[31] M. Saari, A. M. bin Baharudin, P. Sillberg, S. Hyrynsalmi, and W. Yan, “Lora — a survey of recent research trends,” in *2018 41st International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, 2018, pp. 0872–0877. DOI: 10.23919/MIPRO.2018.8400161.

[32] H. Zunair, W. Hasan, K. Zaman, M. I. Haque, and S. Shekhar, “Design and implementation of an iot based monitoring system for inland vessels using multiple sensors network,” Apr. 2018. DOI: 10.1109/ICSSA.2018.8535976.

[33] H. K. Ntale, *The use of the gps system in the water sector*, 2019. [Online]. Available: https://repository.lboro.ac.uk/articles/conference_contribution/The_use_of_the_GPS_system_in_the_water_sector/9594122.

[34] *Bangladesh ferry crash: At least 32 dead as boat capsizes*, 2020. [Online]. Available: https://www.bbc.com/news/world-asia-53190206.

[35] M. Jing and W. Zheng, “Research and application of real-time ship traffic intelligent analysis and calculation platform under 5g background,” *IOP Conference Series: Earth and Environmental Science*, vol. 446, p. 052 093, Mar. 2020. DOI: 10.1088/1755-1315/446/5/052093.

[36] M. Juel and M. Ahmed, “Iot based smart watercraft system,” Nov. 2020. DOI: 10.1109/TENSYMP50017.2020.9230992.

[37] R. Krishnamurthi, A. Kumar, D. Gopinathan, A. Nayyar, and B. Qureshi, "An overview of iot sensor data processing, fusion, and analysis techniques," *Sensors*, vol. 20, no. 21, 2020, ISSN: 1424-8220. DOI: 10.3390/s20216076. [Online]. Available: https://www.mdpi.com/1424-8220/20/21/6076.

[38] A. A. F. Purnama and M. I. Nashiruddin, "Sigfox-based internet of things network planning for advanced metering infrastructure services in urban scenario," in *2020 IEEE International Conference on Industry 4.0, Artificial Intelligence, and Communications Technology (IAICT)*, 2020, pp. 15–20. DOI: 10.1109/IAICT50021.2020.9172022.

[39] A. Ullah, "Smart iot based launch activities monitoring system for reducing the accident occurs on the river," Jun. 2020.

[40] *26 killed in bangladesh boat accident*, 2021. [Online]. Available: https://www.france24.com/en/live-news/20210503-26-killed-in-bangladesh-boat-accident.

[41] *At least 26 killed in bangladesh boat crash*, 2021. [Online]. Available: https://www.aljazeera.com/news/2021/5/3/at-least-26-killed-in-bangladesh-boat-accident.

[42] *At least 39 dead in bangladesh ferry fire*, 2021. [Online]. Available: https://www.aljazeera.com/news/2021/12/24/at-least-32-dead-in-bangladesh-ferry-fire.

[43] *Death toll from bangladesh ferry capsize rises to 34*, 2021. [Online]. Available: https://apnews.com/article/ferry-accidents-dhaka-accidents-bangladesh-1e3c34975d2e54af375f96b6e3bf3824.

[44] M. Mia, M. S. Islam, M. A. Islam, M. Islam, and M. Uddin, "Brief analysis of inland waterway accidents in bangladesh: Causes and solutions," Apr. 2021.

[45] T. S. Adhikary, *Abhijan-10 launch fire: Neglect of duty at every step*, 2022. [Online]. Available: https://www.thedailystar.net/author/tuhin-shubhra-adhikary.

[46] [Online]. Available: https://code.google.com/apis/maps/index.html.

[47] *24 killed as ferry capsizes in bangladesh - times of india*. [Online]. Available: https://timesofindia.indiatimes.com/world/south-asia/24-killed-as-ferry-capsizes-in-Bangladesh/articleshow/8047054.cms.

[48] *Dhaleshwari trawler capsize: 3 more bodies retrieved*. [Online]. Available: https://unb.com.bd/category/bangladesh/dhaleshwari-trawler-capsize-3-more-bodies-retrieved/85618.

[49] S. M. N. Hossain, S. S. Miti, and M. L. Rahman, *Circular water transport system of dhaka city: Analysis of existing condition, inherent problems and future prospects*. [Online]. Available: https://www.bip.org.bd/admin/uploads/bip-publication/publication-9/paper/20140427153257.pdf.