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Website: ijcs.stmikindonesia.ac.id | E-mail: ijcs@stmikindonesia.ac.id

Child drowning prevention: GPS and LoRa based emergency alert system

Md. Rayef Enam[1], Subhasish Ghosh[2], and M. Mesbahuddin Sarker[3]
rayefcse34@gmail.com, subhasish@bgctub.ac.bd, sarker@juniv.edu
[1,3]Institute of Information Technology (IIT), Jahangirnagar University
[2]BGC Trust University Bangladesh

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Abstract

UNICEF recently published in the "Country Office Report 2021" about the mortality of children in Bangladesh, "Every day, 30 children die from drowning – Bangladesh's second leading cause of under-five mortality. Drowning is preventable, and most cases occur within a child's home community." Bangladesh is a country of rivers, which means Bangladesh called a riverine country located in South Asia. The Center for Injury Prevention and Research conducted a survey, Around 19000 people of (all types of ages) drown every year in Bangladesh. Among them, 14500 which mean 77% are children. In our research, the emergency alert system is designed to be cost-effective and user-friendly for village communities in Bangladesh. The system is divided into two components: the kid is equipped with the transmitter, and the receiver is placed at home. The transmitter and receiver both use a LoRa transmission module that can communicate accurately within a 300-meter range (coverage up to 10 Kilometers) and can transmit 256 bytes of data. The transmitter collects geolocation data using a GPS module and sends the data to the receiver using the LoRa module. The receiver module is configured by setting up the geolocation of risky places. The receiver will send SMS or buzzing the receiver to alert the parents when the transmitter or kid is nearby risky places. The Equirectangular approximation method calculates the distance between children's positions from risky areas. Additionally, the transmitter and receiver may communicate encrypted messages using AES 128-bit symmetric encryption technology compatible with Arduino Nano controller. Thus, our emergency alert system can save children from drowning in the home environment.

A. Introduction

This research aims to develop a smartphone based community-driven surveillance service towards safeguarding children from drowning in rivers by using GPS and LoRa based emergency alert system. UNICEF recently published in the "Country Office Report 2021" about the mortality of children in Bangladesh, "Every day, 30 children die from drowning – Bangladesh's second leading cause of under-five mortality. Drowning is preventable, and most cases occur within a child's home community." Bangladesh is a country of rivers, which means Bangladesh called a riverine country located in South Asia. There are 13,000 ponds in Bangladesh and a 2400 km long river (survey of 2015)[1], [2]. The Center for Injury Prevention and Research conducted a survey, Around 19000 people of (all types of ages) drown every year in Bangladesh. Among them, 14500 which mean 77% are children. The group of 1-4 age, most of the time drowned children could not swim, which means those under 4 years old children most of them don't know how to swim[1], [2]. For this reason, every year several children are victims of drowning problem in Bangladesh. To address this newly acknowledged and substantial killer of children, cost-effective, inexpensive, and sustainable technologies appropriate for Bangladesh are unavailable. If these drowning remedies were integrated with current country programs, a large number of these deaths may be avoided each year. The avoidance of these drowning deaths, which usually occur in early life, would result in a rapid drop in early childhood mortality if done at a nationwide level and as an essential element of country programs. Competing health goals, low issue knowledge, the shift of the illness burden to non-communicable diseases, and the multisectoral nature of drowning were four additional aspects that were specific to the instance of drowning[3].

There are advanced technologies like robotic detectors for intrusion detection systems that can be used to monitor river or water reservoir surroundings to detect underage kids nearby and send an alert to surveillance authorities[4]. Drone technologies can be utilized to conduct continuous monitoring to restrain children from entering the dangerous area around the water reservoir [5]. These computer vision-based solutions are complex to operate for village communities in Bangladesh. There are kids' location tracking systems implemented using RFID [6], but the cheap RFID tags are limited in low-range coverage of only centimeters (cm) distance. The GPS-based location tracking system uses a 4.5G/3G/GSM mobile communication system, and the tracking system includes many components like a smartphone application, surveillance server, Google map service subscription, and mobile operator's sms/data service[7]. [8] explores the characterization of the control, convenience, and care settings for present GPS uses, as well as a tentative ethical framework for examining the practicality of GPS location-based services with a focus on accessibility, privacy, accuracy, and property. In Makkah, Saudi Arabia, during the Hajj (Pilgrimage), a system was developed for the identification and tracking of pilgrims. An RFID identifying system that was previously proposed and included into the established system. During the most recent pilgrimage season, the created system underwent effective testing[9]. This research suggests a quick-response mechanism that supports women in difficult situations. She only needs to push the button, and a few pre-defined numbers in terms of latitude and longitude will receive an SMS alert with the harasser's position[10]. The authors of this research examined the individual energy consumption of each GPS tracker component and then developed a revolutionary, tiny, energy-efficient wristband by fusing the most recent LoRa communication and GPS duty cycling technology[11]. The study creates a Haversine approach for localization-restricted distance measuring and estimate. For the implementation model to pinpoint the exact location for the human presence system, signal measurements are combined with wifi position and GPS readings[12]. With the use of the user's device, this study will locate the closest laundry kiosks. Searching for the closest location is made possible by computing the distance between two points of location [13]. The Haversine approach is used to locate the closest recreational area based on the user's location. The findings of this research are intended to assist users in locating the closest tourist attraction to their location and to rank the places according to distance[14]. Instead of locations, the distance from the student residence destination's address is scrutinized. It gives a more accurate picture of the marketing for the following year. The Haversine formula can be used to determine distance[15]. This study compared the two most often used symmetric algorithms, DES (Data Encryption Standard) and AES (Advanced Encryption Standard). A comparison analysis was performed utilizing performance evaluation metrics for each method based on input size[16]. DES, 3DES, AES, RC2, RC6 and Blowfish encryption algorithms were compared with different block size to measure power usage, data transmission throughput and time required for encryption or decryption in the wireless network[17]. AES algorithms were examined, noting their key advantages and disadvantages, as well as the memory utilization of various algorithms.The goal of this research is compatibility of AES with available Ardruino controller with low memory[18].

In our research, the emergency alert system is designed to be cost-effective and user-friendly for village communities in Bangladesh. The system is divided into two components: the kid is equipped with the transmitter, and the receiver is placed at home. The transmitter and receiver both use a LoRa transmission module that can communicate accurately within a 300-meter range (coverage up to 10 Kilometers) and can transmit 256 bytes of data. The transmitter collects geolocation data using a GPS module and sends the data to the receiver using the LoRa module. The receiver module is configured by setting up the geolocation of risky places. The receiver will send SMS or buzzing the receiver to alert the parents when the transmitter or kid is nearby risky places. The Equirectangular approximation method calculates the distance between children's positions from risky areas. Additionally, the transmitter and receiver may communicate encrypted messages using AES 128-bit symmetric encryption technology compatible with Arduino Nano controller. Thus, our emergency alert system can save children from drowning in the home environment.

B. Research Method

1. LoRa TECHNOLOGY

LoRa is a low-power wireless module based on chirp spread spectrum (CSS) technology. It is a long-range, low-bitrate wireless telecommunications system that connects to the Internet and provides a common solution for the Internet of Things[19]. It can also communicate or convey data from a receiver to a transmitter in line of sight. To connect the receiver to the transmitter device, an upgraded LoRa SX1278 Long Range RF Wireless Module was used in this project. Semtech created the LoRa physical layer, which enables long-range, low-power, and low-throughput communications. Depending on where it is deployed, it uses the ISM bands at 433 MHz, 868 MHz, or 915 MHz. When channel aggregation is used, the payload of each transmission can have a range of 2-255 octets, and the data rate can be as high as 50 Kbps. Semtech's unique technology underlies the modulation method. With the help of LoRaWAN's medium access control mechanism, numerous end devices can connect to a gateway and communicate using the LoRa modulation. The LoRa Alliance is developing the LoRaWAN, an open standard, even if the LoRa modulation is a proprietary technology. LoRa is a type of spread spectrum modulation that uses frequency chirps with a linear variation in frequency over time to encode data. Since frequency offsets between the transmitter and receiver are equal to timing offsets in the decoder due to the linearity of the chirp pulses, they may be simply removed. Consequently, this modulation, which is comparable to a frequency offset, is likewise resistant to the Doppler effect. The decoding performance is unaffected by a frequency offset of up to 20% between the transmitter and the receiver. Due to the fact that the crystals inside LoRa transmitters do not need to be made with exceptional accuracy, this helps to lower the price of the transmitters[20]. With a sensitivity of around 130 dBm, LoRa receivers are able to lock on to the frequency chirps received. Forward Error-correction Codes (FECs) are a simple method for correcting interference-related mistakes because the LoRa symbol duration is greater than the typical bursts of AMinterference produced by Frequency Hopping Spread Spectrum (FHSS) systems. The typical co-channel rejection (highest ratio of power between an interferer in the same channel and the LoRa signal) and out-of-channel selectivity (maximum ratio of power between an interferer in a nearby band and the LoRa signal) of LoRa receivers are 90 dB and 20 dB, respectively. As a result, LoRa performs better than conventional modulation techniques like Frequency-Shift Keying (FSK) and is well suited for low-power and long-distance transmissions[20]. The LoRa modulation can be customized using the following parameters: Bandwidth (BW), Spreading Factor (SF), and Code Rate (CR). A forward error correcting code is part of LoRa. These parameters affect the modulation's effective bitrate, resistance to interference noise, and simplicity of decoding. Given that the symbol rate and bit rate are related to the frequency bandwidth at a particular spreading factor, doubling the bandwidth will effectively twice the transmission rate. This is converted into Equation (1), which connects the spreading factor and bandwidth to the length of a symbol (T_s) [20].

$$T_s = \frac{2^{SF}}{BW} \tag{1}$$

Code Rate (CR) = $\frac{4}{4+n}, where\ n \in \{1,2,3,4\}$ and SF bits of information are transmitted per symbol. The Equation (2) calculates bit rate (R_b) [20].

$$R_b = SF \times \frac{BW}{2^{SF}} \times CR \tag{2}$$

For example, a setting with BW = 256 kHz, SF = 8, CR = 4/5 gives a bit rate of R_b= 6.4 kbps.

2. GPS AND LoRa BASED DROWNING PREVENTION SYSTEM HARDWARE

The hardware components required for building the "drowning prevention system" LoRa transmitter and LoRa receiver to share GPS location of the children in shown in Table 1. Arduino (Fig.1) Nano is a small breadboard-friendly board which makes based on an AT- mega328 microcontroller. LoRa (Fig.2) is a Low power wireless module which makes based on spread spectrum mod- ulation techniques derived from chirp spread spectrum (CSS) technology. The NEO-6M GPS module (Fig.3) is a well-performing complete GPS receiver with a built- in ceramic patch antenna which is cost-effective and has high sensitivity. SIM800L Mini GPRS GSM Module is a miniature cellular module used for GPRS transmission, sending and receiving SMS and voice calls.

Table 1. List of system components

No	Components	*Quantity*
1	Arduino Nano V3	2
2	LoRa SX1278 Module	2
3	U-Blox NEO-6M GPS	1
4	SIM800L/ESP8266Wifi Module	1
5	3.3v Regulator-AMS1117	1
6	Capacitor - 1000uF	1
7	Capacitor - 220uF	1
8	Potentiometer - 103, 10k	1
9	LCD Display/Monitor	1

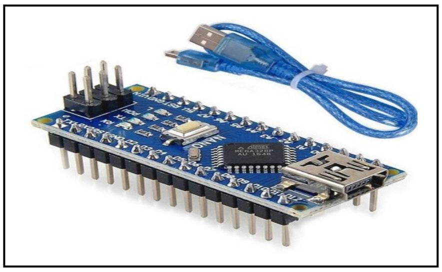

Figure 1. Arduino Nano V3

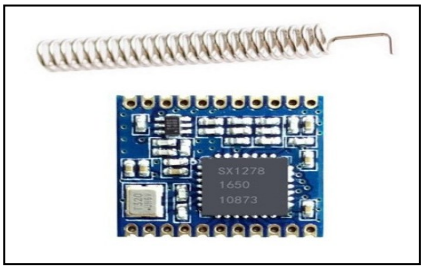

Figure 2. LoRa SX1278 LoRa

Figure 3. U-Blox NEO-6M GPS

3. GPS AND LoRa BASED DROWNING PREVENTION SYSTEM CIRCUIT DESIGN

There are two main parts to this project: one's Transmitter and another one is the Receiver. The Fig. 4 shows a physical diagram of LoRa transmitter how to connect the GPS Module and LoRa Module with Arduino Nano V3.The second major part of this project is the LoRa Receiver which makes a combination of Arduino Nano, LoRa Module, and SIM Module shown in Fig. 5. In Fig. 6 the location of the LoRa transmitter is viewed as Latitude and Longitude values in LCD display of the LoRa receiver. Point-to-point communication topology is used to connect the LoRa transmitter and receiver in this system. Therefore, the LoRa receiver can receive signals from multiple transmitters if they are transmitting at different time intervals.

The important component of LoRa modules is Antenna. Lora module transmits in specific frequency ranges. The license-free megahertz radio frequency bands are: 433MHz in Asia, 868MHz in Europe and 915MHz in North America. While setting up the LoRa transmission in the application we have selected the frequency 433E6 instead of 866E6 and 915E6 since our system will work in Bangladesh.

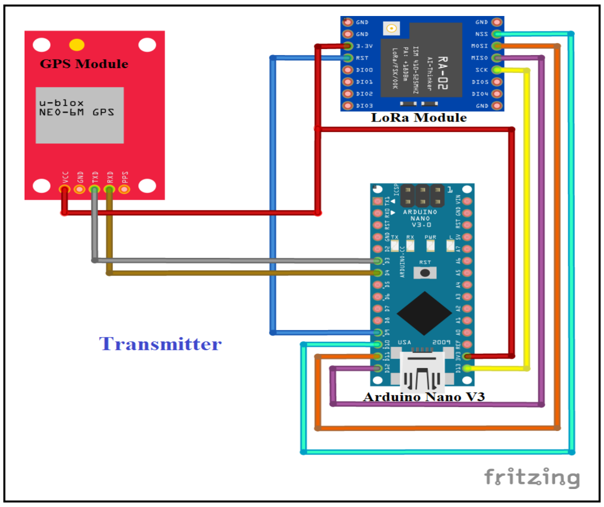

Figure 4. LoRa transmitter & GPS

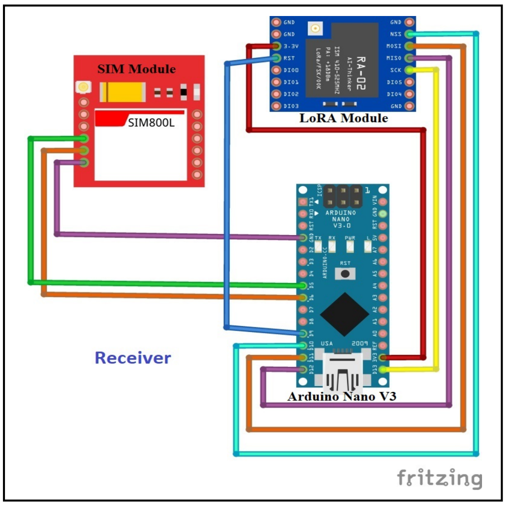

Figure 5. LoRa receiver

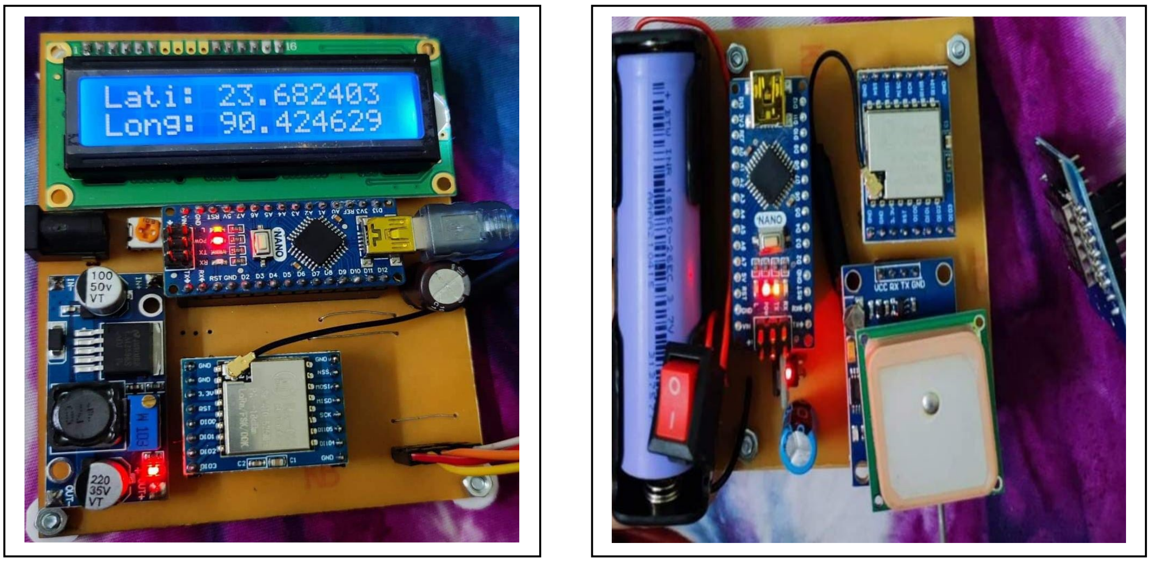

Figure 6. LoRa Receiver LCD display: longitude, latitude of LoRa

4. GPS DISTANCE CALCULATION SYSTEM BETWEEN TWO LOCATIONS WITH LATITUDE AND LONGITUDE POINTS

The three primary methods for calculating geographic distances from latitude and longitude data are the Haversine formula, the spherical law of cosines, and the equirectangular approximation. The distance between the devices is determined using an equirectangular approximation because the GPS computation in this study is performed between the LoRa transmitter and LoRa receiver devices[21]. If two points located in a great-circle the Haversine formula may be used to calculate the distance. This implies that measurement of the two location point's shortest distance over the earth's surface. The Haversine formula is shown in Equation (3.1, 3.2, and 3.3).

$$a = sin^2\left(\frac{\Delta\varphi}{2}\right) + cos\varphi 1. cos\varphi 2. sin^2\left(\frac{\Delta\lambda}{2}\right) \quad (3.1)$$

$$c = 2\ .atan2(\sqrt{a}, \sqrt{1-a}) \quad (3.2)$$

$$d = R.c \quad (3.3)$$

where latitude= φ, longitude= λ, R (earth's radius) = 6,371km

The simpler spherical law of cosines method is a reasonable preference to the Haversine method because it can give results down to the smallest distances like a few meters. The Spherical Law of cosines formula is given in Equation (4).

$$d = \text{acos}(sin\varphi 1. sin\varphi 2 + cos\varphi 1. cos\varphi 2. cos\Delta\lambda).\text{R} \quad (4)$$

The Pythagorean theorem on Equirectangular approximation shown in Figure 7 and the formula given in Equation (5.1, 5.2, and 5.3) can calculate small distances between two locations points with a high performance.

$$x = \Delta\lambda.\cos(\varphi_m) \quad (5.1)$$

$$y = \Delta\varphi \quad (5.2)$$

$$d = R.\sqrt{(x^2 + y^2)} \quad (5.3)$$

where Δφ = (latitude2-latitude1), Δλ = (longitude2-lonongitude1), φ_m=($\varphi_1 + \varphi_2$)/2, R (earth's radius) = 6,371km

The Pythagorean Theorem calculates the GPS distance in Equation (5.3).

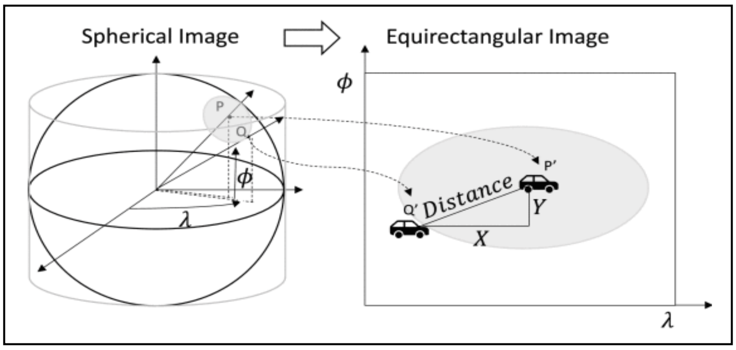

Figure 7: Equirectangular approximation[21]

The spherical law of cosines is a bit slower than the haversine despite being simpler. Programming language, processor speed, coding context, accessible trigonometric functions, and whether an equirectangular approximation is better appropriate for extremely small distances may all influence the decision. Table.2

shows the comparative experimentation results of different GPS locations distance calculation systems.

Table 2. Comparison result among GPS distance calculation methods

GPS distance calculation methods	Calulculated Distance (meters)	*Location 1*	*Location 2*
Haversine	10.95724666977396	22.3475, 91.8122	22.347466, 91.8123
spherical law of cosines	10.957524048625926	22.3475, 91.8122	22.347466, 91.8123
Equirectangular approximation	10.957246669707166	22.3475, 91.8122	22.347466, 91.8123

5. PROPOSED DROWNING PREVENTION METHODOLOGY

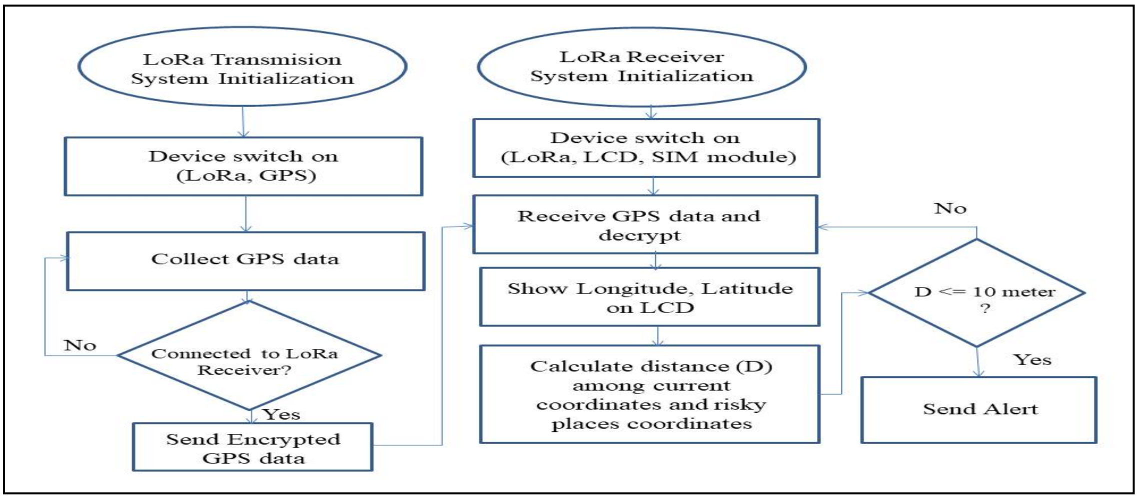

Figure 8. Children safety alerting process using LoRa and GPS

Figure.8 shows the emergency alert operation process to save children from going to risky places in the village using the LoRa transmitter, GPS, and LoRa receiver devices. In this research, we have used Equirectangular approximation method to calculate the distance between the GPS position of the transmitter and GPS coordinates of dangerous places. If the distance is less than 10 meters, the alert system will send an alert to the parents. Fig.6 shows the longitude and latitude of the GPS location of the transmitter in the receiver LCD.

C. Result and Discussion

The receiver device is established outside the house in the open air. We have kept a record of the receiver's Received Signal Strength Indication (RSSI) values while the kid is wandering around with the transmitter device. The following Fig. 9 shows the RSSI values of the received signal measured in dBm to the distance between the transmitter and receiver.

If RSSI=-30dBm: signal is strong. If RSSI=-120dBm: the signal is weak. The LoRa based Drowning prevention system can be used efficiently for tracking the kids within maximum 300 meters area according to RSSI values shown in Table 3 and Figure 9. The Figure 10 shows the simulation experiment result of distance measurement by using Equirectangular approximation formula. The Proteus IoT builder is used to build the circuit design and simulation. The website called "The Engineering Projects" provides the Proteus Arduino UNO libraries. There are several rounds of testing by simulation to compare with different known distances between locations are done. The experimentation shows that the distances are calculated correctly in each round.

Table 3. Distance from the receiver and Received Signal Strength Indication (RSSI)

No	*Distance (meter)*	RSSI (-dBm) (Average)
1	10	20.5
2	50	53.4
3	100	71.0
4	150	74.8

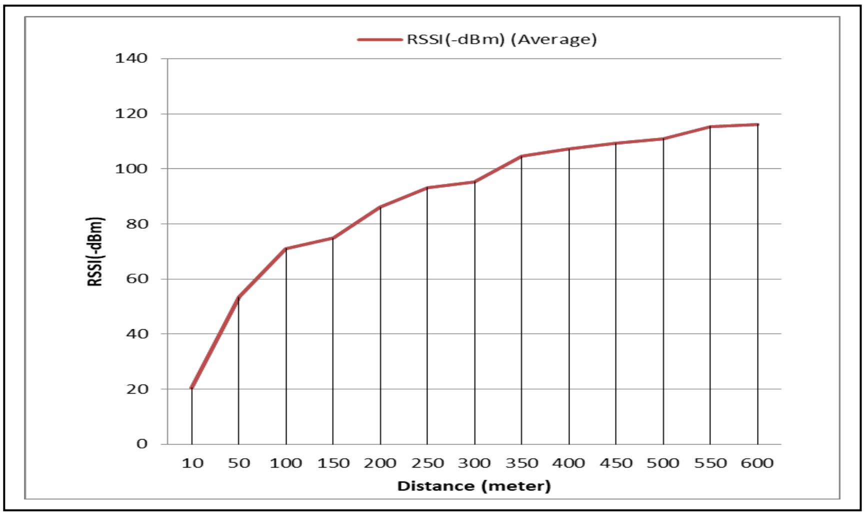

Figure 9. RSSI values to distance graph

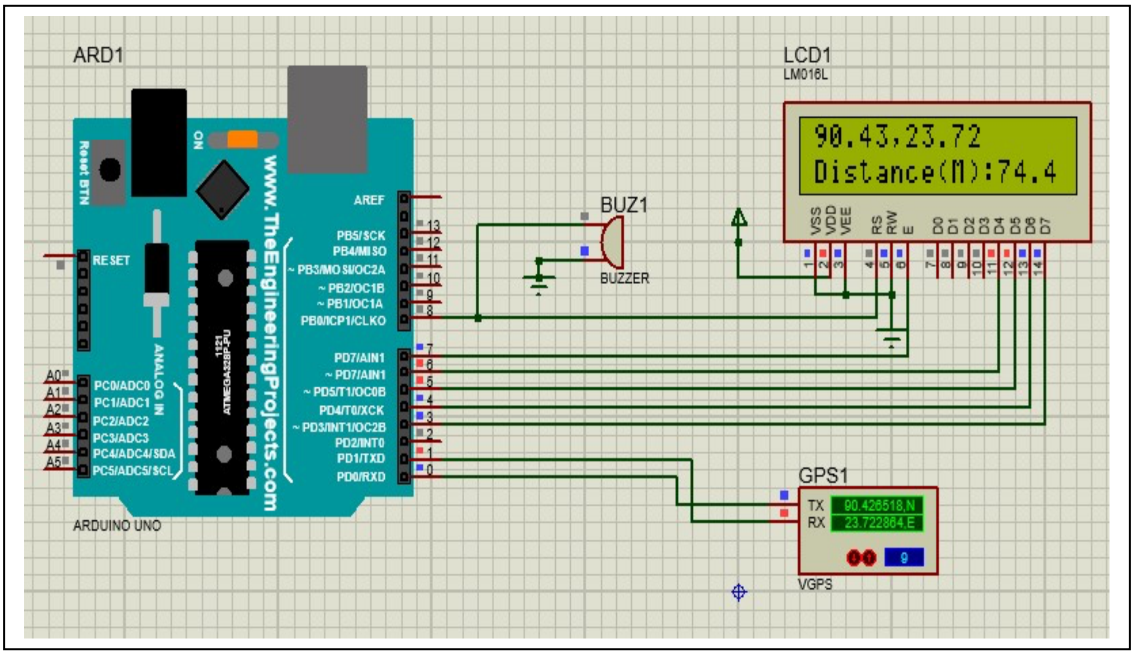

Figure 10. Simulation of Equirectangular approximation formula using GPS module

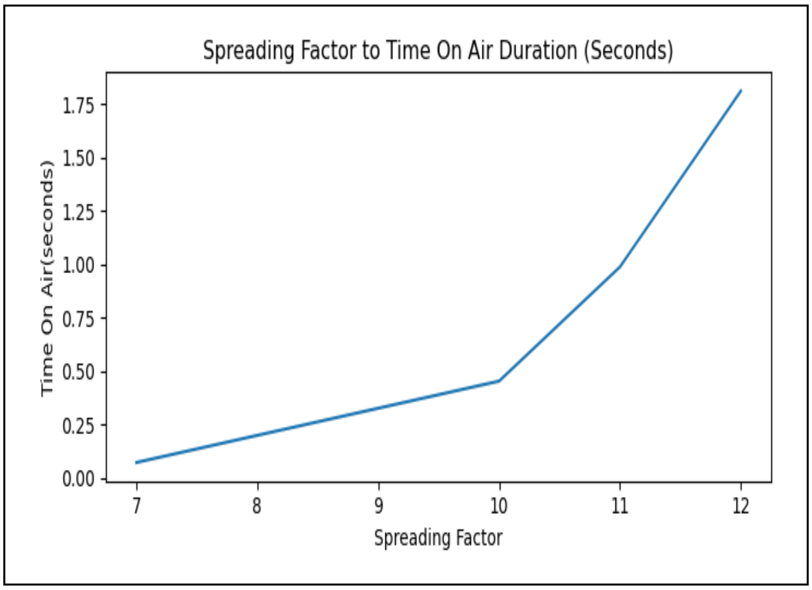

Figure 11. Spreading Factor (SF) proportional to Time-on-Air duration

Using NS3 simulator LoRAWan module, a lorawan topology is designed with 10 LoRA devices where 8 end nodes, 1 gateway connected with 1 network server using PPP protocol. RandomWalk2dMobilityModel is used to simulate the mobility of the end nodes. The spreading factor is changed in the range of 7 to 12. The effect of changing spreading factor (SF) on Time on Air Duration (Second) is linearly increasing beacuse the spreading factor increases number of Lora symbols hence the time on air duration; this is shown in Figure 11. According to Equation (2) the higher the spreading factor the lower the bit rate for a fixed bandwidth. This implies that SF 7 will provide higher bit rate than SF 10 and as such needs less Time-on-Air duration. As higher SF requires longer Time-on-Air which shortens the battery life of LoRA end nodes.

D. Conclusion

By combining a GPS and LoRa-based emergency alert system, this research intends to create community-driven surveillance service to protect kids from drowning in rivers. The system has been tested, which works properly for child security and will play an important role in reducing the drowning problem. The proposed system can accurately alert parents about children entering the risky area by sending SMS or buzzing the receiver device. The Equirectangular approximation method calculates the distance between children's positions from risky areas. The LoRa based Drowning prevention system can be used efficiently for tracking the kids within maximum 300 meters area. Different types of gps distance calculation systems are compared and experimented and it is found that Equirectangular approximation method is good for measuring small distance within less amount of time. Also, the LoRa transmitter and receiver can transmit strong signal in a longer range when they are kept in open areas. The LoRa technology provides strong penetrating ability, low power consumption for terminal devices, and interference-free signal transmission.

E. References

[1] Md. J. Hossain, Md. Al-Mamun, M. Alam, Mst. R. Khatun, Md. M. R. Sarker, and Md. R. Islam, "Child drownings in Bangladesh: need for action," *bmjpo*, vol. 6, no. 1, p. e001464, Jun. 2022, doi: 10.1136/bmjpo-2022-001464.

[2] A. Rahman *et al.*, "Analysis of the childhood fatal drowning situation in Bangladesh: exploring prevention measures for low-income countries," *Injury Prevention*, vol. 15, no. 2, pp. 75–79, Apr. 2009, doi: 10.1136/ip.2008.020123.

[3] M. Dodd, A. Zwi, A. Rahman, F. K. Chowdhury, R. Q. Ivers, and J. Jagnoor, "Keeping afloat: a case study tracing the emergence of drowning prevention as a health issue in Bangladesh 1999–2017," *Injury Prevention*, vol. 27, no. 4, pp. 300–307, Aug. 2021, doi: 10.1136/injuryprev-2020-043720.

[4] M. Golshekan and A. Davoudi Kiakalayeh, "Advanced technologies in drowning prevention," *J Inj Violence Res*, vol. 14, no. 2 Suppl 1, p. Paper No. 4, Jan. 2022.

[5] R. Trumpeter, "Utilising Drone Technology for Drowning Prevention," *Utilising Drone Technology for Drowning Prevention*, Mar. 20, 2023. https://www.linkedin.com/pulse/utilising-drone-technology-drowning-prevention-ryan-trumpeter (accessed Mar. 25, 2023).

[6] Z. Gul, "RFID Based School Bus Tracking and Security System," *Safe and Sound Security*, Aug. 18, 2021. https://getsafeandsound.com/2021/08/rfid-based-school-bus-tracking-and-security-system/ (accessed Mar. 25, 2023).

[7] A. Bhoyar, "GPS based real time vehicle tracking system for kid's safety using RFID and GSM," 2018.

[8] K. Michael, A. McNamee, and M. Michael, "The Emerging Ethics of Humancentric GPS Tracking and Monitoring," in *2006 International Conference on Mobile Business*, Copenhagen: IEEE, Jun. 2006, pp. 34–34. doi: 10.1109/ICMB.2006.43.

[9] M. Mohandes, "Pilgrim tracking and identification using the mobile phone," in *2011 IEEE 15th International Symposium on Consumer Electronics (ISCE)*, Jun. 2011, pp. 196–199. doi: 10.1109/ISCE.2011.5973812.

[10] S. S. Kumbhar, S. K. Jadhav, P. A. Nalawade, and Y. Mutawalli, "WOMEN SECURITY SYSTEM USING GSM AND GPS," vol. 05, no. 03, Mar. 2018.

[11] T. Hadwen, V. Smallbon, Q. Zhang, and M. D'Souza, "Energy efficient LoRa GPS tracker for dementia patients," in *2017 39th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, Jul. 2017, pp. 771–774. doi: 10.1109/EMBC.2017.8036938.

[12] E. Winarno, W. Hadikurniawati, and R. N. Rosso, "Location based service for presence system using haversine method," in *2017 International Conference on Innovative and Creative Information Technology (ICITech)*, Nov. 2017, pp. 1–4. doi: 10.1109/INNOCIT.2017.8319153.

[13] A. Dwi Hartanto, Moh. R. Susanto, I. Ilham, H. Dardjito, R. Retnaningsih, and H. Nurdiyanto, "Mobile Technologies of Formulation Haversine Application and Location Based Service," in *Proceedings of the Joint Workshop KO2PI and The 1st International Conference on Advance & Scientific Innovation*, Medan, Indonesia: EAI, 2018. doi: 10.4108/eai.23-4-2018.2277593.

[14] Z. Arifin, M. R. Ibrahim, and H. R. Hatta, "Nearest tourism site searching using Haversine method," in *2016 3rd International Conference on Information*

Technology, Computer, and Electrical Engineering (ICITACEE), Oct. 2016, pp. 293–296. doi: 10.1109/ICITACEE.2016.7892458.
[15] V. Hegde, T. S. Aswathi, and R. Sidharth, “Student residential distance calculation using Haversine formulation and visualization through GoogleMap for admission analysis,” in *2016 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC)*, Dec. 2016, pp. 1–5. doi: 10.1109/ICCIC.2016.7919699.
[16] S. Srilaya and S. Velampalli, “Performance Evaluation for DES and AES Algorithms- An Comprehensive Overview,” in *2018 3rd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)*, May 2018, pp. 1264–1270. doi: 10.1109/RTEICT42901.2018.9012536.
[17] D.-D. Salama, H. Abd elkader, and M. M. Hadhoud, “Performance Evaluation of Symmetric Encryption Algorithms on Power Consumption for Wireless Devices,” *International Journal of Computer Theory and Engineering*, pp. 343–351, Jan. 2009, doi: 10.7763/IJCTE.2009.V1.54.
[18] T. Ismat, “Comparative analysis of AES algorithms and implementation of AES in Arduino,” Thesis, BRAC University, 2015. Accessed: May 10, 2023. [Online]. Available: http://dspace.bracu.ac.bd/xmlui/handle/10361/4889
[19] A. Augustin, J. Yi, T. Clausen, and W. M. Townsley, “A Study of LoRa: Long Range & Low Power Networks for the Internet of Things,” *Sensors*, vol. 16, no. 9, Art. no. 9, Sep. 2016, doi: 10.3390/s16091466.
[20] Semtech Corporation, “SX1280/SX1281: Long Range, Low Power, 2.4 GHz Transceiver with Ranging Capability,” Mar. 29, 2020. https://semtech.my.salesforce.com/sfc/p/#E0000000JelG/a/2R000000HoCW/8EVYKPLcthcKCB_cKzApAc6Xf6tAHtn9.UKcOh7SNmg (accessed May 11, 2023).
[21] D. Na and S. Park, “Blockchain-Based Dashcam Video Management Method for Data Sharing and Integrity in V2V Network,” *IEEE Access*, vol. 10, pp. 3307–3319, 2022, doi: 10.1109/ACCESS.2022.3140419.