Geofencing Application using IRNSS/NavIC

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Abstract—**With the development of the Global Positioning System and other Navigation Satellite Systems, it is possible to locate position coordinates precisely. The growth of smart devices and high-speed data connectivity has also supported the development of applications using location information. Geofencing is a major field of location-based services that enables remote monitoring of pre-defined boundaries. This paper describes various applications of geofencing and presents a novel approach to child safety application using geofencing. A hardware setup is designed to send position coordinates of a child in real-time. A mobile application is developed for parents to monitor their children remotely. They can set up a geofence in the app and receive alerts when the child goes out of bounds. The geofencing application utilizes NavIC at its core.**

Index Terms—**Geofencing, IRNSS, Security, Mobile Application**

I. Introduction

The success of mobile internet and GPS-enabled smartphones has created a market for novel applications using location information. These applications are called Location-Based Services (LBS), which filter information and services depending on the current location of the user. The last decade has enabled new features to LBS like geofencing and background tracks. Geofencing allows users to draw a virtual perimeter around a point/object and monitor when a location-aware device enters or exits a geofenced area. Under this definition, it does not directly prevent the functioning of the device/ user [1].

While the word geofencing has not yet entered common usage, it has been researched for years to enable a new generation of mobile applications, services and business models. Solutions developed in the transport sector include vehicle tracking and fleet management. Other sectors include human resources, defence, and marketing for promoting advertisements within the geofence area. Table 1 presents various geofencing applications reviewed.

The application we have focused on is child safety using geofence. Every year there are countless incidents regarding missing children and abduction cases. Over 59,000 cases were reported in the year 2020 in India [4]. Geofencing can be used to monitor and track child movements remotely. Special consideration is to develop a child safety device for children not equipped with smartphones and prevent its excessive usage. This device is constrained for low-power consumption and small size to allow easy usage or fit in as an accessory.

TABLE I
Applications of Geofencing

Use	Example
Fleet Management	When a truck driver breaks from his route, the dispatcher receives an alert [2]
Human Resources	A smart card that can alert the management if a person tries to enter an unauthorized area [2]
Defence & Security	Keep track of potential movement of hazardous material and preventing potential attacks
Marketing	A restaurant can trigger a text message about day specials when the customers enter the geofenced area [3]
Asset Management	An RFID tag on package can alert if it is taken away from the warehouse
Monitoring	A badge or locket to check children or elderly people when they exit the geofenced area

The paper is organized by incorporating a depth concept of the geofence, its hardware, and software implementation part in section 2. Following that, section 3 comprises the proposed methodology with the results related to child safety using a geofence. Lastly, the conclusion is added.

II. Conceptualization Geofencing

Geofencing is gathering attention as a technology for next-generation Location Based Services (LBS). It creates a virtual perimeter, either by defining a new boundary or creating a virtual fence around an existing boundary. General applications use circular geofences with two parameters - the point of interest and the radius 50m to 50,000m [5]. For high precision and the need to replicate real-world boundaries, applications use polygon geofences. These are more accurate than circular geofences but more complex as the parameters include each

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corner and edge defined. The geofencing application will generate a notification when a location-aware device enters or exits a geofenced area. Fig.1 and Fig.2 shows a circular geofence and a polygon geofence respectively

Fig. 1. Circular Geofence [6]

Fig. 2. Polygon Geofence [6]

In general, a geofencing application includes four segments:

1) *A spatial element:* Global Navigation Satellite Systems such as IRNSS, GPS, GLONASS, EGNOS or the nearest access point send the location coordinates.
2) *A communication element:* Mobile telecommunication operators or satellite systems in remote areas send information to the control centre or database.
3) *An application segment:* Interfacing solutions that can be mobile application based or web applications.
4) *A user segment:* The onboard unit connected to spatial element and control centre. A mobile device such as a smartphone, tablet [7].

The research carried out in this project is focused on developing a child safety application. The scope of our work is for children who travel without the companionship of adults/parents. A geofencing application would be suitable as it allows remote monitoring and a satellite-based system would allow precise location updates in real-time. As a part of this application, we proposed a hardware resource equipped with NavIC (Navigation with Indian Constellation) receiver to send the location coordinates of the child in real-time and a mobile application to allow remote monitoring. The hardware device can be carried by children and update location information to the mobile app. Parents/Adults can define a geofence as a safe zone for their children and receive alerts if children cross the geofenced area. The following subsection describes the geofencing utilization in detail.

A. Hardware Device

Hardware such as computers and smartphones are the physical component that stores and runs instructions provided by the software. In the present scenario, smartphones are well equipped with GPS receivers to allow navigation and other LBS. In our case, the hardware includes a microcontroller and receiver module to receive NavIC + GPS satellite signals and transmit location coordinates. This device is specialized for its function- sending location coordinates every 1s and allows usage of LBS without the need for smartphones.

The *spatial segment* of the geofencing application is the satellite system that sends the location coordinates. NavIC is an independent satellite-based navigation system developed by the Indian Space Research Organization (ISRO), it aims to provide position, navigation and timing services over India and its neighbourhood area up to 1500km. A constellation of 8 satellites, provides high accuracy of 1m in public and 10cm under restricted areas. We have used the S1216F8-G13 satellite navigation receiver developed by SkyTrak, capable of using L5 NavIC, L1 GAGAN/GPS/GLONASS signals to provide data. Fig. 3 shows the block diagram of the receiver module as mentioned in the datasheet.

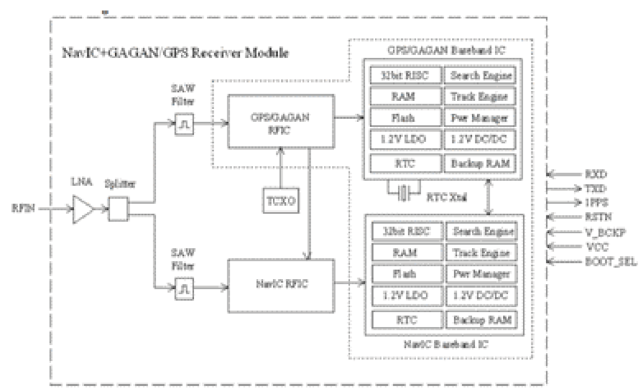

Fig. 3. SkyTrak S1216F8- G13 (NavIC + GPS receiver) block diagram

The SkyTrak receiver will receive the satellite information in the National Marine Electronics Association (NMEA) data format and the microcontroller retrieves the latitude and longitude values at a time instance. This microcontroller is assigned an identification number called NodeID to distinguish between multiple devices. It forms the *user segment* of the geofencing application. The microcontroller used is NodeMCU, an open-source IoT platform. The module considered is a custom ESP32 based development board with an onboard 2G/GPRS module SIM800C. The new board combines ESP32 WiFi and Bluetooth with the SIMCom SIM800C GPRS module. The SIM800C GPRS module allows global connectivity and forms the *communication segment* of the geofencing application.

B. Mobile Application

The *application segment* of the geofencing application is the mobile application 'Child Safety App' allows parents to set up a geofence and remotely monitor their child in real-time. The status of a child (within or outside geofence) will display on the map screen.

The development of mobile applications takes in parts of the front-end and backend. The front-end is the development of the mobile User Interface (UI), converting the input data into its corresponding symbolic representation of various features available on the application. Mobile apps include confidential details such as passwords, authentication details, the location. These mobile apps also need signup and login and require a database to store this information. All of this information is maintained in the backend – a necessary part of a mobile app that stores, secures and processes the data in the background.

To develop the mobile app, three methods are analysed:

1) Native mobile development to run on a particular operating system
2) Cross platform development so that applications are compatible with multiple operating systems
3) Hybrid app development which is the combination of native development and web application

The Frontend development uses ReactNative framework which is a Cross-Platform App development approach. Applications developed using ReactNative Framework could run on different platforms like iOS and Android. The app development started at Expo. Expo is a framework and a platform for universal React applications. It is a set of tools and services built to the top of ReactNative. Using Expo, setting up a project is easy and can be done in a minute. Sharing the app is easy via QR-code or link, instead of sending the .apk or .ipa file to share the app. With Expo, building and deploying ReactNative apps is easy for both iOS and Android platforms. Codes can be tested on mobile phones using Expo Go. So the use of Expo fastens the development projects based on ReactNative.

Authentication is a key parameter for security. For this, we have used the Firebase database which allows users to develop mobile and web applications. Firebase Authentication provides backend services, easy-to-use SDKs, and ready-made UI libraries to authenticate users to the app. It supports authentication using passwords, phone numbers, popular federated identity providers like Google, Facebook and Twitter, and more. For authorizing the user in the "Child Safety App", Firebase authentication service is used. For Storing the real-time latitude and longitude of the child coordinate, a database is required. Firebase provides a real-time database service. It stores and syncs data with our NoSQL cloud database. Data is synced across all clients in real-time and remains available when the app goes offline. Its keep features are real-time, offline, accessible from client devices, and Scale across multiple databases. A flow chart depicting the working of the mobile application is shown here in Fig. 4.

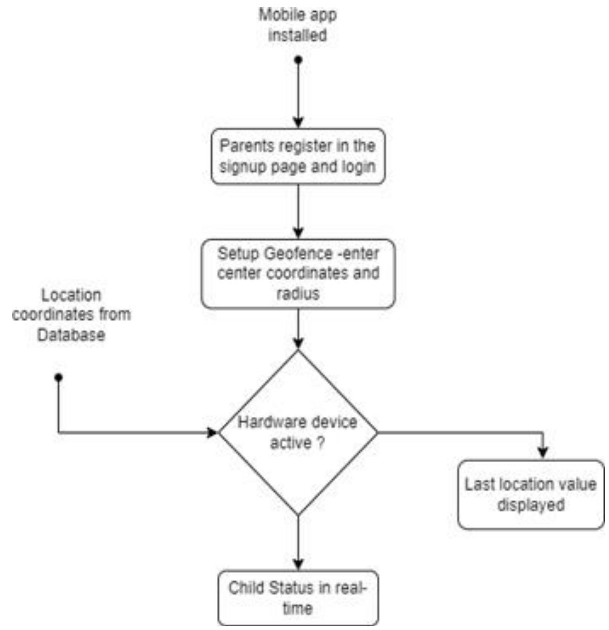

Fig. 4. Mobile Application Flowchart

C. Geofencing Implementation

The main algorithm of the mobile app is to monitor the geofence and display its status. Geofence can be monitored based on three events namely Enter, Exist and Dwell. Enter is when device/user enters the geofence, Exit is when device/user leave the geofence and dwell is when device/user moves inside the geofence. Fig. 5 shows the circular geofence on the map.

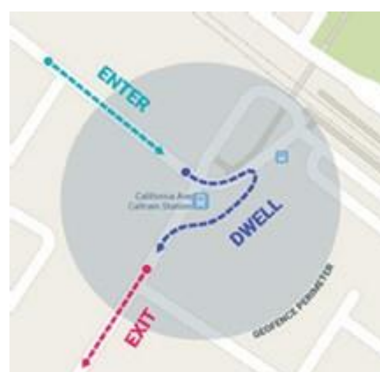

Fig. 5. Geofencing [5]

To determine the entry, exit and dwell, it is required to calculate the minimum distance between Parent Location and Child Location. The location data is in form of latitude and longitude so the Haversine formula is used to calculate the great-circle distance between two points that is, the shortest distance over the earth's surface. Haversine formula is an important equation in navigation. Generally, Haversine is used for computing the great circle distances between two pairs of coordinates on a sphere. The calculations here assume Earth as spherical (ignoring ellipsoidal effects). [9].

The haversine can be expressed in trigonometric function as:

$$\text{haversine}\ (\phi) = \sin^2(\phi/2) \tag{1}$$

The haversine of the central angle (which is d/r) is calculated by the following formula:

$$d/r = \sin^2(\Delta\phi) + \cos\phi 1 \cdot \cos\phi 2 \cdot \sin^2(\Delta\lambda) \tag{2}$$

where r is the radius of the earth (6371 km), d is the distance between two points $\varphi 1\phi 2$, is the latitude of the two points, and $\lambda 1, \lambda 2$ is the longitude of the two points respectively. Solving d by applying the inverse haversine or by using the inverse sine function in (3), we get the distance in km.

$$d = 2\sin^{-1}\sqrt{\sin^2(\Delta\phi/2) + \cos\phi 1 \cdot \cos\phi 2 \cdot \sin^2(\Delta\lambda/2)} \tag{3}$$

To monitor the child, if the distance between child and parent location (calculated using haversine formula) is less than geofence circle radius then the child is inside the geofence (dwell event) and if the distance is greater than the radius then the child has exited the geofence (exit event). If an exit event is triggered, the alert is given to the parent using the mobile application. The function calculateDistance which implements the above algorithm is shown below:

```
function calculateDistance(lat2, long2, lat1,
long1) {
  var R = 6371; // Radius of the earth in km
  var dLat = deg2rad(lat2 - lat1);
  var dLon = deg2rad(long2 - long1);
  var a =
    Math.sin(dLat / 2) * Math.sin(dLat / 2) +
    Math.cos(deg2rad(lat1)) *
    Math.cos(deg2rad(lat2)) *
    Math.sin(dLon / 2) *
    Math.sin(dLon / 2);
  var c = 2 * Math.atan2(Math.sqrt(a),
    Math.sqrt(1 - a));
  var d = R * c; // Distance in km
  return d;
}
```

III. Proposed Methodology

The geofencing application is divided into three main parts: hardware, backend + database and geofence mobile application. The block diagram in Fig. 6 shows the complete structure.

Hardware band includes NavIC receiver and NodeMCU with SIM800C. NavIC is interfaced with NodeMCU using Serial Universal Asynchronous Receiver Transmitter (UART) Protocol. The data received from NavIC+GPS module is saved in a database. Geofence Mobile App UI consists of Login Screen, SignUp Screen, a screen to enter the geofence details which shows the circular geofence as defined by parent and displayed on a mobile screen for real-time child tracking. Backend Server manages the request coming from Geofence App and sends back the response. It also interacts with the Database using Create, Read, Update, Delete (CRUD) operation.This section presents the test results at different stage of implementation as a process flow.

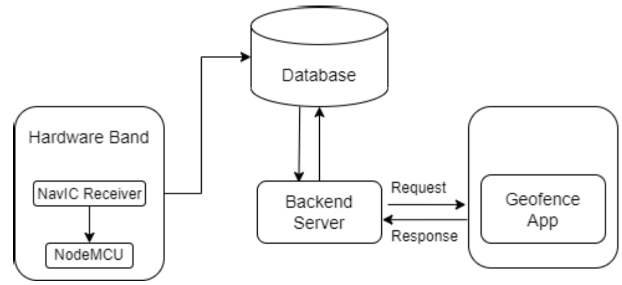

Fig. 6. Proposed System Design

Test Circuit: To depict the circuit connections in Fig. 7, NavIC is interfaced with NodeMCU by Universal Asynchronous Receiver Transmitter(UART) protocol.The Transmitter(TX) pin of NodeMCU is connected with the Receiver(RX) pin of NavIC and the RX pin of the NodeMCU is connected to the TX pin of NavIC. NavIC is powered by connecting 3V3 pin with 3V3 pin of NodeMCU. Finally NodeMCU is powered by Micro USB connector 5V.

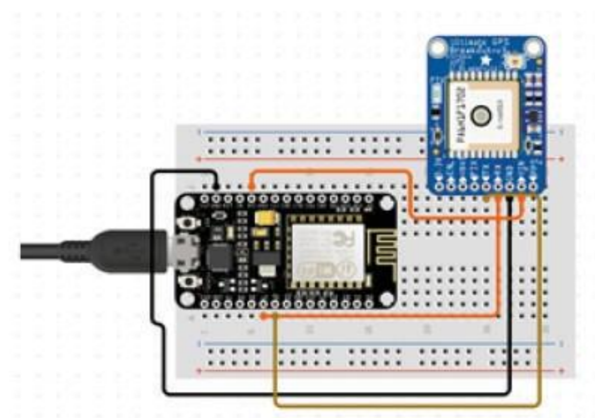

Fig. 7. Circuit Diagram

Receiving NMEA data: The data from NavIC+GPS receiver is received in NMEA format. Fig. 8 shows the data received on serial monitor at 115200 baud rate.

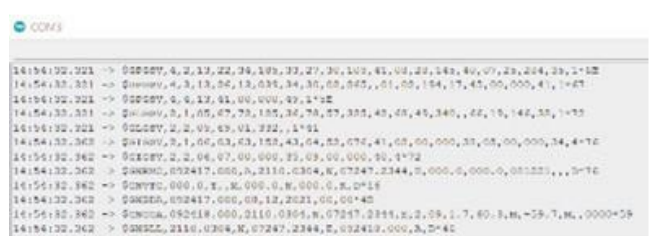

Fig. 8. NMEA data received on Serial Monitor

Connecting to database: The hardware (microcontroller and NavIC receiver) is responsible for sending the location coordinates of child to database and backend. When the latitude and longitude values are parsed from NMEA data, these values are sent to Firebase database. The real-time database uses NodeID to separate different coordinates received. The NodeID also ensures scalability and mainitainance of the geofence application.

Fig. 9. Position coordinates received in database. For active node with *NodeID 0001*, latitude and longitude values are received.

Mobile app signup and login: Parents/Adult can sign-up in the Child safety app by registering their details and child's details - Child name, Child age, email and password. The combination of email and the Node ID is unique to every user where Node ID is the unique ID of Hardware Band. Once registered, they can login and set geofence by entering the coordinates of point of interest and the radius for which geofence is to be generated. The point of interest defines the center of circular geofence,which is considered the parents location. Fig. 10 and Fig. 11 shows snippets from the mobile application.

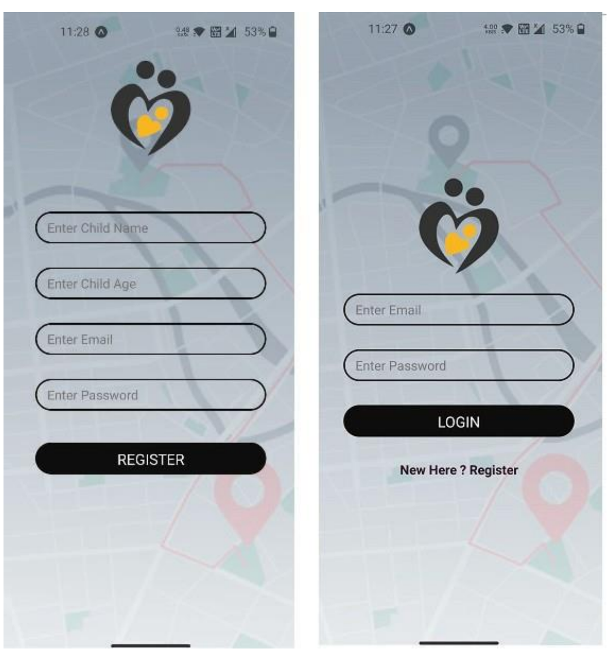

Fig. 10. Mobile App (*Register screen and Login screen*)

Geofence status: After successful setup of geofence, the mobile application shows the geofence in real time and extracts the location coordinates of child from database. As in Fig. 12,

Fig. 11. Mobile App- setup geofence

location marker of child is used to show current location of child. If the child crosses geofence, the status and the distance is changed and parent mobile device is notified.

Fig. 12. Geofence pages. Note that status changes (*inside or outside*) depending upon the location of child.

IV. Conclusion

We introduced the concept of geofencing and reviewed the different applications of geofencing in transport and logistics management, human resource management, defense and healthcare sectors. We propose child safety as an application of geofencing and develop a mobile application to allow parents to monitor their children in a circular geofence.

Microcontroller-based hardware can send location coordinates in real-time, reducing the need for smartphones in children. The geofencing application uses NavIC+GPS, a global navigation satellite system focused on India and its neighbourhood area. The project can be further expanded to develop multiple child support, sending SMS alerts with timestamps and other upgrades. The development uses open-source technologies and the test results are presented in this paper.

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