Implementation of a Navigation System for a Moving Sea Ice on an Android Device

By

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Abstract

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DEDICATION AND ACKNOWLEDGEMENTS

Here goes the dedication.

Author's declaration

I declare that the work in this dissertation was carried out in accordance with the requirements of the University's Regulations and Code of Practice for Research Degree Programmes and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, the work is the candidate's own work. Work done in collaboration with, or with the assistance of, others, is indicated as such. Any views expressed in the dissertation are those of the author.

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CHAPTER 1

INTRODUCTION

To enhance the understanding of the regional and global consequences of Arctic climate change and sea-ice loss and improve weather and climate predictions, **A**lfred **W**egener **I**nstitute (AWI) in coordination with its partners is undertaking the **M**ultidisciplinary drifting **O**bservatory for the **S**tudy of **A**rctic **C**limate (MOSAiC) expedition which will be the first year-round expedition into the central Arctic exploring the Arctic climate system. The MOSAiC expedition aims to monitor the movement of a large Sea Ice over an extended period of time.

1.1 Section

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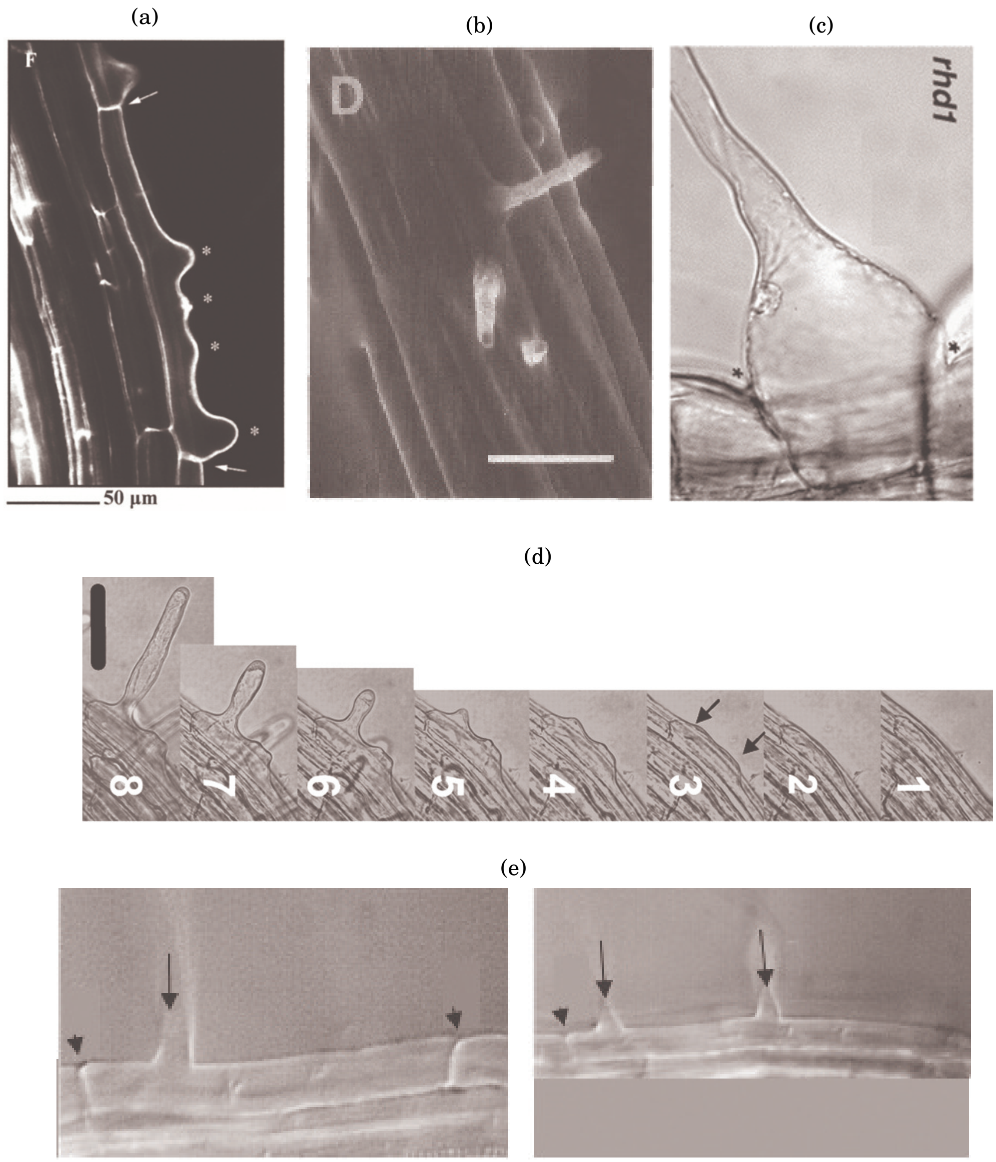

FIGURE 1.1. (a) A mutant RH cell. Asterisks show multiple sites of RH initiation in a single root hair cell (indicated by the arrows). Figure reproduced from [**?**]. (b) Hair-forming cell with three RH initiation locations. The bar represents $50\mu m$. Figure reproduced from [5]. (c) Large bump in mutant *rhd1*. Figure reproduced from [3]. (d) Mutant overexpressing gene *ROP2*; from right-hand to left-hand, numbers indicate progressive snapshots at different times. RH initiation sites are indicated by the arrows. The bar represents $75\mu m$. Figure reproduced from [4]. (e) Mutants affected by auxin. On the left-hand side, RH site is farther away from the apical end (left arrow cap); on the right-hand side, multiple RH locations (arrows). Figure reproduced from [7].

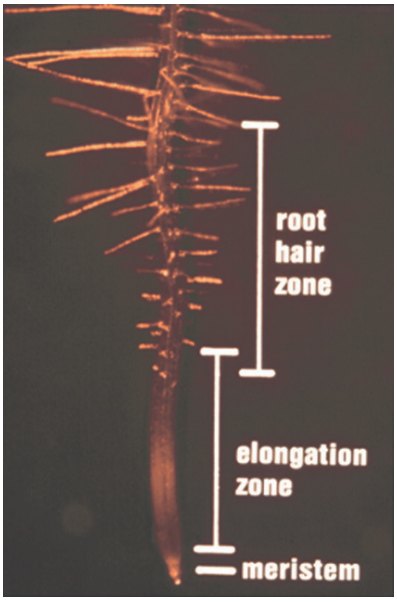

FIGURE 1.2. Developmental zones of an Arabidopsis root. Figure reproduced from [3].

CHAPTER 2

System Overview

This section gives an overview of the Geographic Coordinate System. It will briefly introduce the concept of geographic coordinates and the Global Positioning System and how physical locations are mapped to coordinates on a 2D plane. It also gives a detailed description of the custom coordinate system, which is derived from the Global Coordinate System, that is implemented as part of the Floe Navigation System.

2.1 Geographic Coordinate System

The purpose of any coordinate system is to specify a location on a

2.2 Mapping

The Floe Navigation System projects the Geographic coordinate system on to a 2D plane with Latitude along the y-axis and Longitude along the x-axis. The intersection of the prime meridian and the equator (0°, 0°) is the origin of the 2D plane. The mapping is done in such a fashion that 1° along the latitude axis represents 60 Nautical Miles. Since the Earth is not a perfect sphere and longitudinal lines are closer together at poles and farther apart near the equator so 1° along the longitude axis represents 60 M at the equator and as we move towards the poles the distance represented by 1° decreases by a factor cosine of the latitude. So, on the longitude axis, 1° represents $60\,\mathrm{M} \times \cos(latitude)$.

2.3 Custom Coordinate System

The Custom Coordinate System is a Cartesian Coordinate System established on the Ice Floe. As with any Cartesian Coordinate System, each point is expressed as an ordered pair. The elements of the ordered pair represent the distance measured from an axis. The first element of the ordered pair is the distance from the x-axis and is called the x-coordinate and second element of the ordered pair is the distance from y-axis and is called the y-coordinate [8].The Custom Coordinate

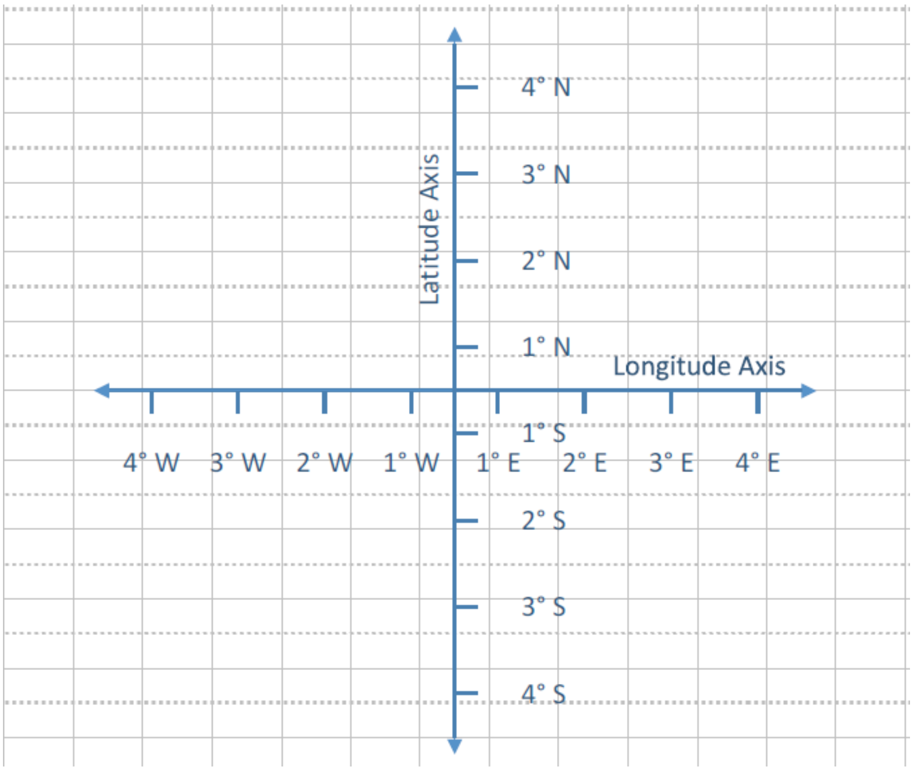

FIGURE 2.1. Map Projection.

System within the Geographic Coordinate System is shown in Figure 2.2
The Floe Navigation System needs at least two AIS transponders to create the coordinate system which is formed by designating one AIS transponder as an origin of the coordinate system (called the Origin Station) and another AIS transponder is used to mark the direction of the x-axis (called the x-Axis Marker). The y-axis of the coordinate system is considered perpendicular to the x-axis. The AIS transponder moves with Sea Ice and broadcast their geographical coordinates periodically with the movement. As the Geographical coordinates are updated, the system recalculates the coordinate system and the position of all the objects (stations and other points of interest) marked on the coordinate system along with it.

2.3.1 Angle Beta

The mapping from the Geographic coordinates to the custom coordinate system is done by calculating the angle between the x-Axis (marked by the two AIS transponders: Origin Station and x-Axis Marker) of the custom coordinate system and the Geographic Longitudinal direction. The angle of the custom coordinate system's x-Axis to the Geographic Longitudinal axis is called Beta angle denoted by β.
The angle β is calculated by calculating the initial bearing angle from the Origin Station to the x-Axis Marker using the Haversine formula. The Haversine formula is a method of computing two points on a sphere given their latitude and longitude. It is derived from the spherical law of cosines [2]. According to the Haversine formula given the latitude and longitude of two points the

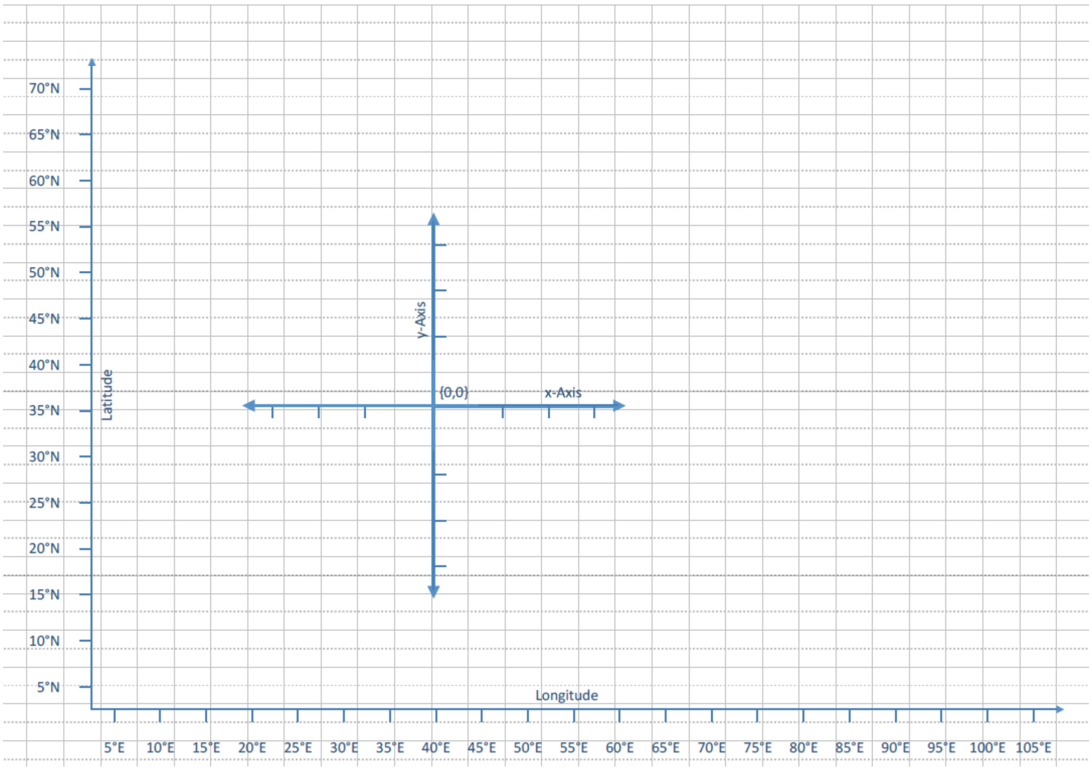

FIGURE 2.2. Custom Coordinate System within Geographic Coordinate System.

initial bearing is given by 4.1 [6]

$$\theta = \tan^{-1} \frac{\sin(\Delta\lambda)\cdot\cos(\phi_2)}{\cos(\phi_1)\cdot\sin(\phi_2) - \sin(\phi_1)\cdot\cos(\phi_2)\cdot\cos(\Delta\lambda)} \tag{4.1}$$

where:

θ = Bearing
ϕ_1 = Latitude of First Point
λ_1 = Longitude of First Point
ϕ_2 = Latitude of Second Point
λ_2 = Longitude of Second Point
$\Delta\lambda$ = Difference in Longitude

Every new Fixed Station (mounted with an AIS Transponder) that is installed is specified by its distance from the origin and the angle α it makes with the x-Axis of the custom coordinate system. A simplified version of this scenario is shown in Figure 2.3. The angle α and the distance for all Fixed Station are considered to be constant[1] and the angle β can be recalculated from the constant α and distance from each Fixed Station.
The value of angle β is updated at regular time intervals (10 s) by calculating a new value from the location data received from each Fixed Stations and averaging it; so that if any of the Fixed

[1]This distance may change with the Expansion/Shear of the Floe. However, for simplification purposes, the distance is assumed constant.

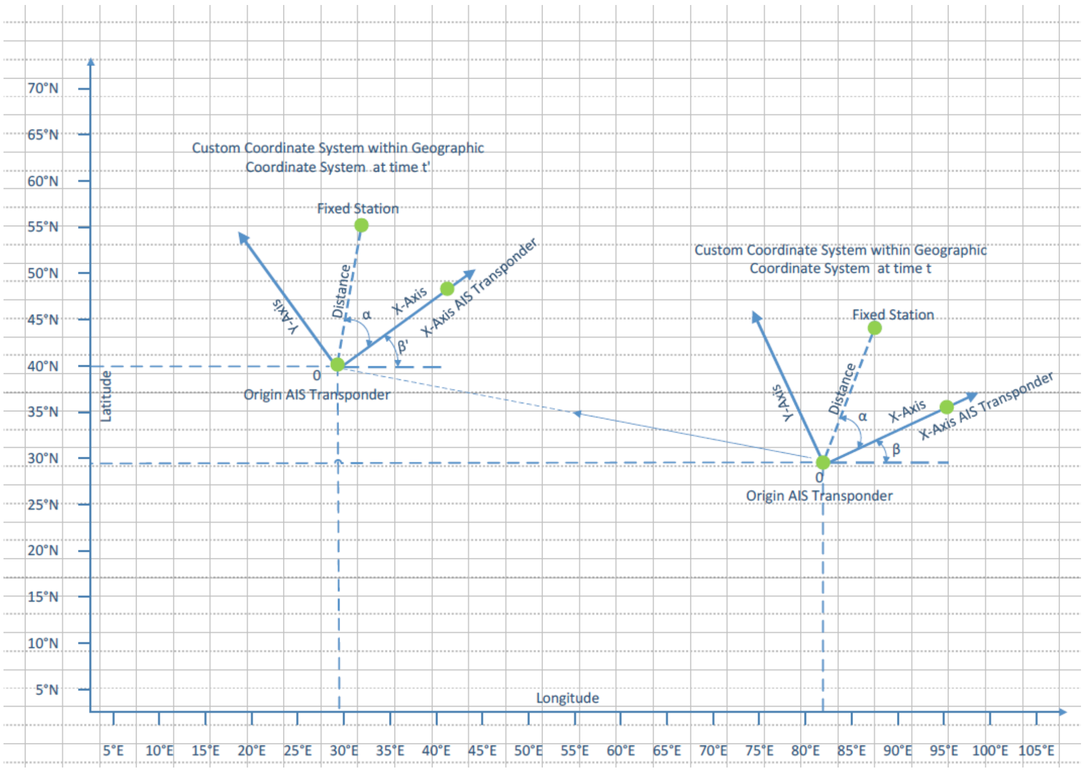

FIGURE 2.3. Custom Coordinate System with Angle Beta.

Stations (including the origin and x-Axis marker) breaks away from the Ice, it does not affect the value of β greatly and the coordinate system persists. So, the coordinate system is independent of the Fixed Stations; as long as there are two Fixed Stations installed the system can function.
AIS Transponders which are not installed as Fixed Station are shown as Mobile Stations and for each of these mobile stations, the app calculates the angle α and distance at regular time intervals from the location data received from the AIS Transponder.
There are certain points on the Sea Ice which do not have an AIS Station mounted such as Static Stations or Waypoints. For these points, the system calculates the angle α and distance from origin using the tablet's location at the time of installation. As these points are considered to be stationary on the Ice, these parameters are not recalculated again and it remains constant unless the point is recovered.

CHAPTER 3

SYSTEM DESIGN

This section gives an overview of the Geographic Coordinate System. It will briefly introduce the concept of geographic coordinates and the Global Positioning System and how physical locations are mapped to coordinates on a 2D plane. It also gives a detailed description of the custom coordinate system, which is derived from the Global Coordinate System, that is implemented as part of the Floe Navigation System.

3.1 Floe Navigation App Architecture

Add Description after name and screenshots are updated.The Floe Navigation App needs to calculate several important parameters at regular intervals to ensure that the coordinate system is calculated correctly and the points installed on the coordinate system are also placed properly. As shown in figure 3.1 the App uses several Services to ensure that the calculations are done correctly and at regular intervals. These Services run along with the App and are running as long as the App is running. However, when the App is used for the first time and the Coordinate System is not established yet, not all Services are running as some of these services can only work if there is a working coordinate system. Figure 3.2 shows the services, which are running before Grid Initial Configuration is completed.

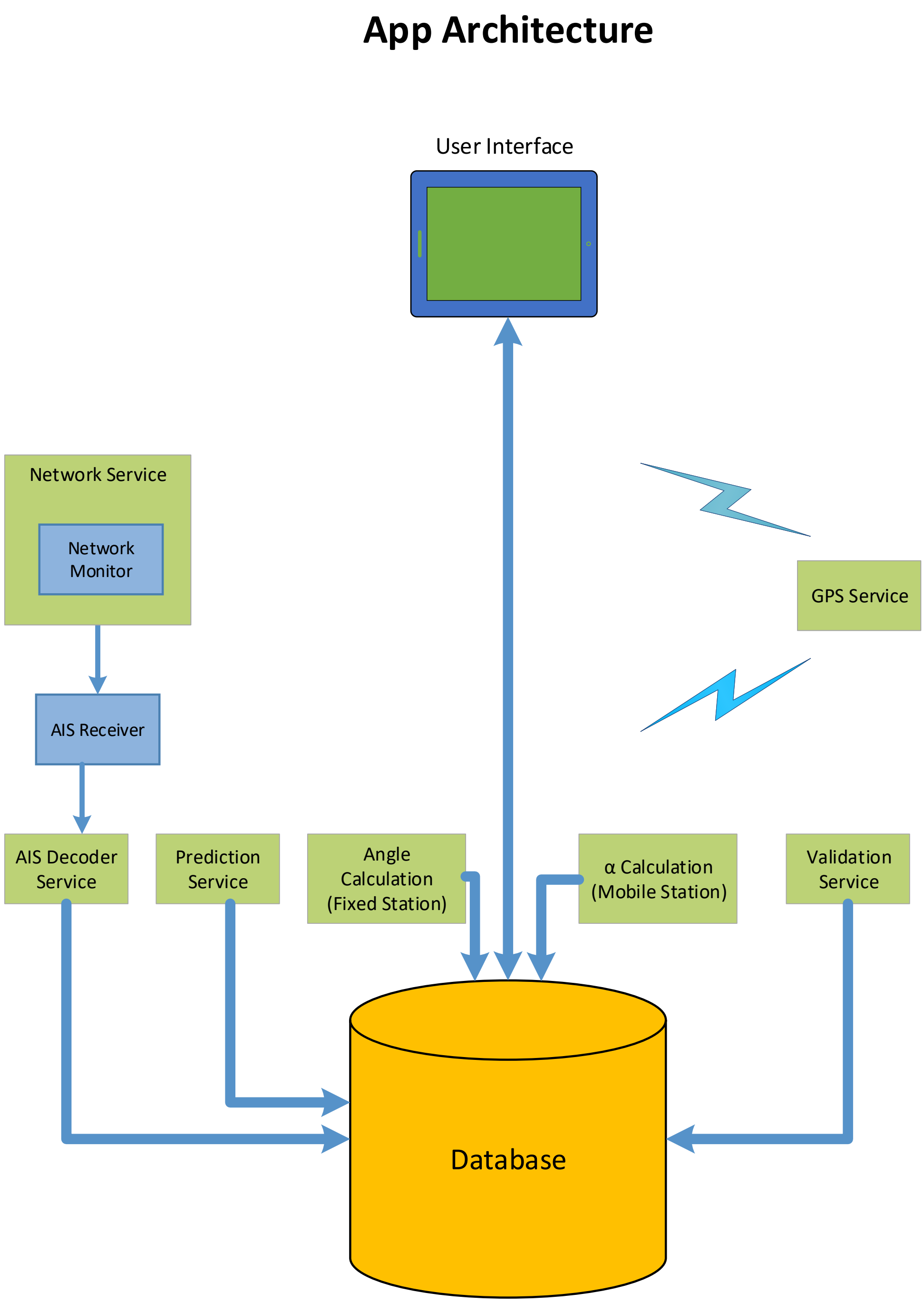

FIGURE 3.1. Floe Navigation App Architecture.

3.2 Services

The Floe Navigation App needs to calculate several important parameters at regular intervals to ensure that the coordinate system is calculated correctly and the points installed on the coordinate system are also placed properly. As shown in figure 3.1 the App uses several Services to ensure that the calculations are done correctly and at regular intervals.
These Services run along with the App and are running as long as the App is running. However, when the App is used for the first time and the Coordinate System is not established yet, not all Services are running as some of these services can only work if there is a working coordinate system. Figure 3.2 shows the services, which are running before the initial configuration of the grid is completed.

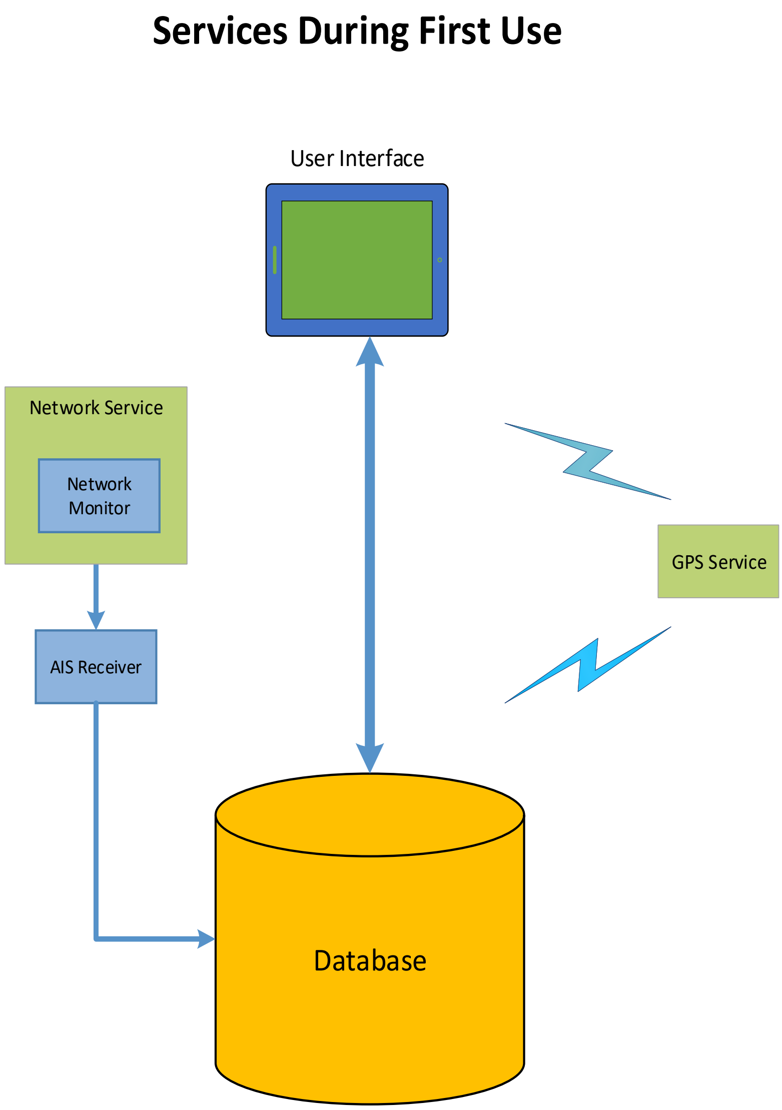

FIGURE 3.2. Running Services during first use.

3.2.1 GPS Service

GPS Service is responsible for reading the current location of the tablet and synchronizing time with the GPS Clock time. It runs in an individual thread and reads the location data from the GPS Provider within the tablet. The GPS provider does not use the Network Location Provider which uses internet and mobile network instead it uses satellite fix to determine the location of the device because of which the location fix may not work indoors.
The GPS Service does not write the location to any particular location in the database instead it broadcasts the location data and other activities or services can read the location data from the broadcast. The GPS Service runs every 30 s.

3.2.2 Network Service

The Network Service ensures the connectivity of the App to the Wi-Fi network of an AIS transponder. It runs a Network Monitor thread which pings the AIS transponder every 5 s. The Network Monitor thread, in turn, starts another thread called AIS Message Receiver which then creates a Telnet Connection with the AIS transponder and starts receiving AIS Data using a buffered reader.
If the ping drops the already running AIS Message Receiver thread is terminated, and as soon as the ping is restored, the Network Monitor thread starts a new AIS Message Receiver thread so as to reestablish the Telnet Client.

3.2.3 AIS Decoding Service

The AIS Decoding Service as its name suggests is responsible for decoding the incoming AIS packets. As explained previously the AIS Message Receiver thread creates a Telnet client which reads the incoming data using a buffered reader which can read the data line by line instead of byte by byte. As soon as a complete AIS packet is read, the AIS Message Receiver thread starts an AIS Decoding Service and passes it the packet.
The AIS Decoding Service then decodes the AIS Packet (for details on decoding check code documentation) and checks the MMSI of the incoming packet. If the MMSI is a Fixed Station it writes the data to the Fixed Station table otherwise it writes the data to the Mobile Station Table.
As the AIS Decoding Service is an Intent Service it runs in its own thread. However, as soon as its work is done and it has written the AIS data to the database it dies automatically.
The AIS Decoding Service can only decode AIS packets of Type 1, 2, 3, 5, 18 and 24. For details on AIS Packet types and the information contained therein check **Add Chapter Reference**.

3.2.4 Alpha Calculation Service

This service calculates the position of each Mobile Station on the coordinate system. As explained in Chapter 2, any point on the coordinate system can be determined by the angle it makes with the x-Axis (α) and the distance from the origin. As Mobile Stations can move on the Floe their angle α and distance need to be calculated at regular interval to ensure that the Mobile Stations are shown correctly on the Grid.
The Alpha Calculation Service reads the mobile station data – such as latitude, longitude, speed over ground and course over ground – from the database and for each mobile station calculates the angle θ it makes with the Geographical Longitudinal Direction as shown in figure 3.3. Then

it calculates the difference between the angles θ and β which gives α. The Alpha Calculation Service calculates the distance from the origin using the Haversine formula (**Citation**).
The Alpha Calculation Service runs every 10 s. So, the position of each mobile station on the grid is updated every 10 s as well.

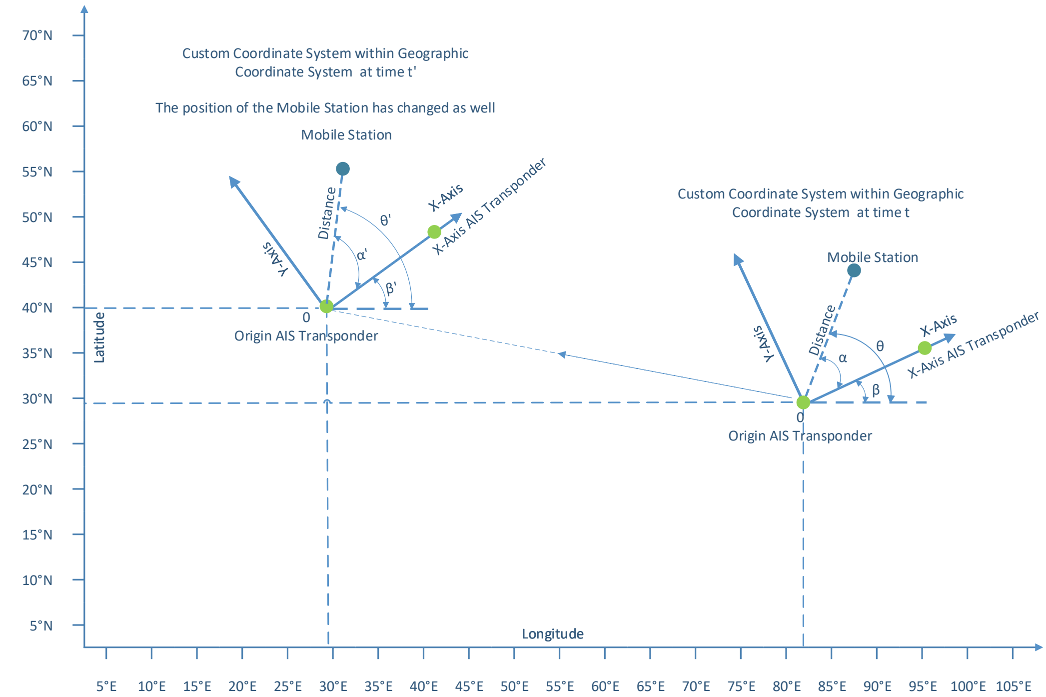

FIGURE 3.3. Mobile Stations within Coordinate System.

3.2.5 Angle Calculation Service

This Service is responsible for maintaining the coordinate system within the Geographical Coordinates. It updates the value of the angle β which is used to create the coordinate system. The angle β is calculated by using the fixed angle α and the distance from the origin of each Fixed Station. The new value for β is the average of the β calculated for each Fixed Station. This Service runs every 10 s.

3.2.6 Prediction Service

Most of the AIS transponders mounted on the Sea Ice are Class B AIS transponders which send their location data every 3 min. However, for the Floe Navigation System, the update rate is much higher than 3 min which means that the position of each Fixed Station on the Ice needs to be interpolated. Additionally, the predicted values can also help in detecting breakages in the Sea Ice by comparing the predicted values with the received values.
This Service predicts the position of each Fixed Station on the Ice at a much higher regular interval. It uses the Haversine formula (**Citation**) to calculate the position. For each station, it

reads the current Latitude, Longitude, Speed Over Ground and Course Over Ground values and predicts what the Latitude and Longitude of that station will be in 10 s time. This Service also runs every 10 s.

3.2.7 Validation Service

This Service is used to detect if a Fixed Station has broken off from the Floe. It calculates the difference in distance between the Predicted Coordinates (from the Prediction Service) and the Received Coordinates (from the AIS Decoding Service) and if the difference is more than a specified amount it marks the prediction as a wrong prediction. If several consecutive predictions go wrong within a specified interval of time for a given station that station is then removed from the Fixed Station table, is no longer used for calculations by other Services and is no longer visible on the Grid as a Fixed Station. In the special case when the origin station or the x-Axis marker station break off, the Floe Navigation App only removes their MMSI from the AIS Station list table so that the incoming data from these MMSI is not used for calculations. However, the Floe Navigation App keeps on showing a Fixed Station at the origin (with the MMSI 1000) or x-Axis marker (with the MMSI 1001) to preserve the grid visually. The difference in the distance which can mark a prediction wrong is defined by the `ERROR_THRESHOLD` configuration parameter, and the time interval is defined by the `PREDICTION_ACCURACY_THRESHOLD` configuration parameter. For details on the configuration parameters check **Include Configuration Section**.

CHAPTER 4

Implementation Consideration

This section gives an overview of the Development tools used for the implementation of the Floe Navigation System. It will briefly introduce the software development tools used to create the App. It also gives a detailed description of the setup procedure of the development environment in which the Floe Navigation System was implemented.

4.1 Development Environment

The Floe Navigation System consists of the Floe Navigation App and the Synchronization Server; each of which is developed in a separate environment. The Floe Navigation App is developed in Android and the Synchronization Server consists of a MySQL Database and PHP based Web-services. Table 4.1 shows the layers that are visible on the Grid by default along with their respective icons.

Application	**Version**[1]
Java JRE	1.8.0_52
Android Studio	3.2.1
Eclipse IDE[2]	Neon.3 Release (4.6.3)
MySQL[2]	8.0
Postman[2]	6.6.0
Microsoft Internet Information Services[2]	10.0.17134.1

TABLE 4.1. Applications Used in System Development.

[1] Versions used for developing Floe Navigation App version 1.0.0.

[2] Used only for Synchronization. For changes in the App which do not affect the Synchronization process, you will only need Android Studio.

4.1.1 Setting Up Android Development Environment

The Floe Navigation App was developed using Android Studio. Android Studio is the official Integrated Development Environment (IDE) for development of Android Apps. Android Studio is connected to the tablet using Android Debug Bridge (ADB). The Android Debug Bridge is a software-interface for the Android system, which can be used to connect an android device with a computer using a USB cable or a wireless connection [1].
However, the tablet used in this system (XSLATE D10) does not support a USB Slave connection [9] for debugging and through testing it was observed that the WiFi Access Point of the AIS Transponder em-trak B360 does not support more than one client simultaneously. In addition to the Wifi and the USB interfaces, the tablet also has an Ethernet interface [9], however, Android does not support multiple network interfaces simultaneously so when connecting with ADB over Ethernet the tablet will not be able to connect to the WiFi network of the AIS Transponder. So Bluetooth tethering was used to connect the tablet with the PC over ADB for code debugging and flashing and the Wifi interface was available for connection with the AIS transponder.
Follow the steps below to setup ADB over Bluetooth:

1. Enable Developer Options and Android Debugging on the tablet by going to Settings → System → About Phone and tap the Build Number 7 times.

2. Connect the PC to the tablet via Ethernet and assign Static IPs to both the tablet and the PC. Static IP Assignment on the tablet XSLATE D10 is shown in figure 4.1

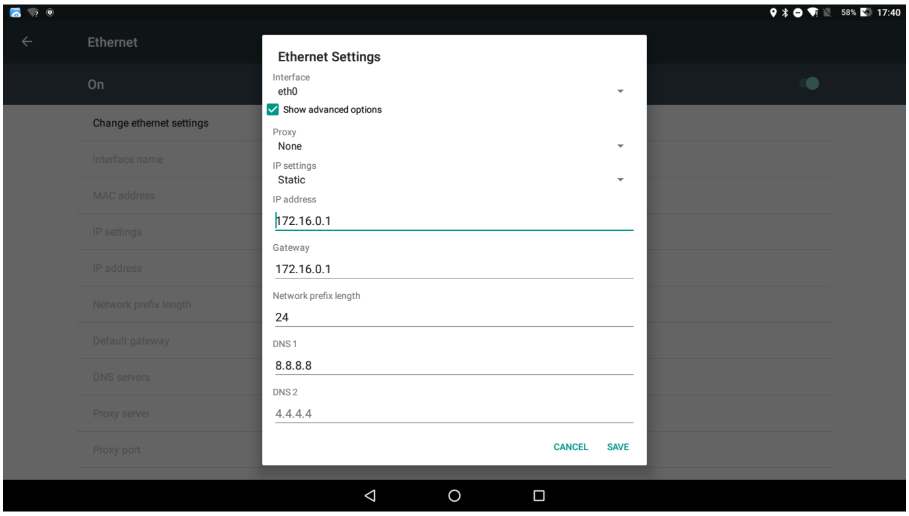

FIGURE 4.1. Assigning Static IP to Ethernet Connection on the Tablet.

3. Open a Command Prompt window on the PC and start Android Debugging Bridge (ADB) in TCP IP mode by entering the following commands (Enter the IP of the tablet):

```
>adb connect ***.***.***.***
>adb tcpip 4455
```

4. Enable Bluetooth on the tablet and pair the tablet with the PC.

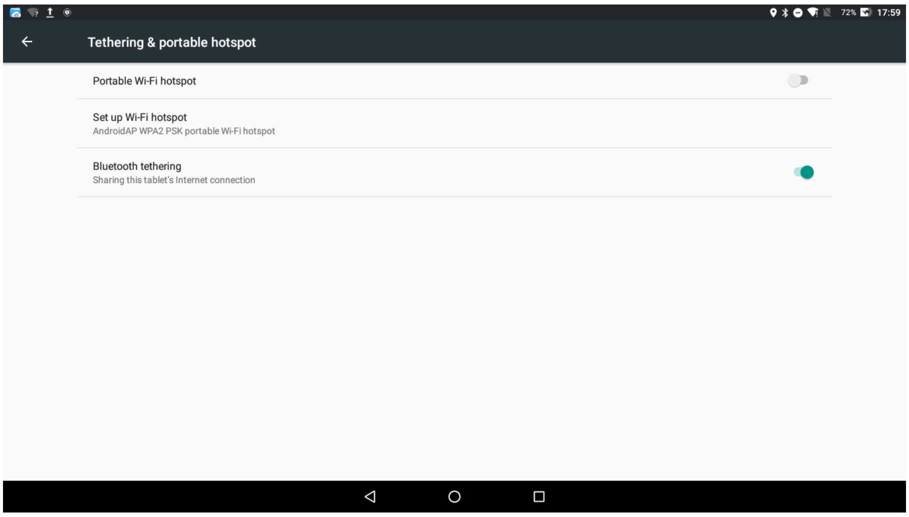

FIGURE 4.2. Enabling Bluetooth Tethering on tablet.

5. On the tablet go to Settings→More→Tethering & portable hotspot and enable Bluetooth tethering as shown in figure 4.2.

6. On the PC go to Control Panel→Devices and Printers and right-click on the tablet and click on Connect Using→Access Point as shown in figure 4.3.

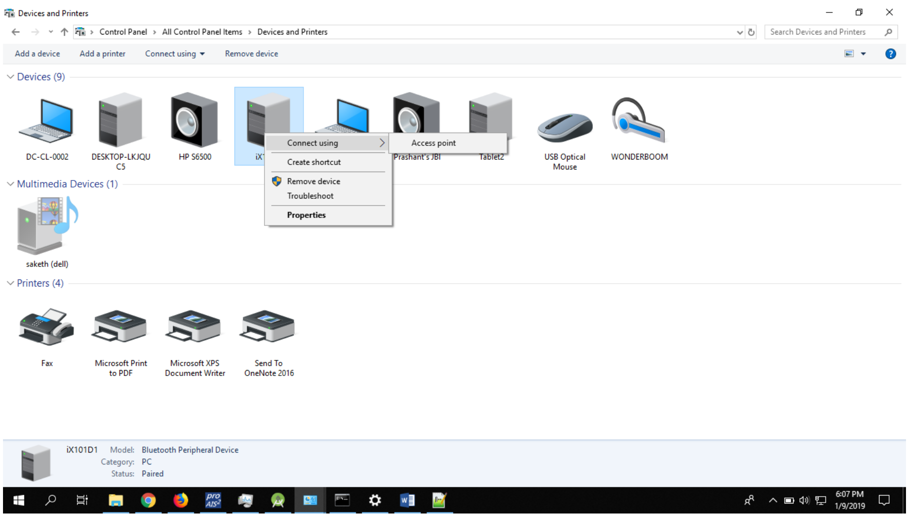

FIGURE 4.3. Connect to Bluetooth Access Point.**Insert better screenshot**

If on right-clicking the tablet and Connect Using shows Direct Connection instead of Access Point try unpairing and repairing the tablet with the PC.

7. Now go back to the command prompt and enter:

```
>adb connect 192.168.44.1:4455
```

The PC is now connected to the tablet and you can deploy your App to the tablet and/or debug it as can be seen from figure 4.4.

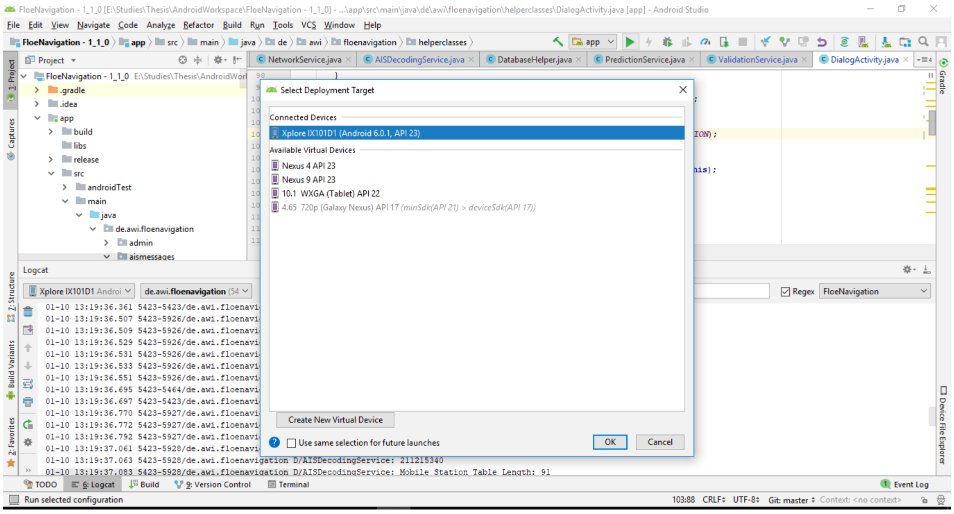

FIGURE 4.4. App Deployment from Android Studio using ADB over Bluetooth. **Insert better screenshot**

The logs from the tablet can also be viewed using the Logcat window in Android Studio as can be seen from figure 4.5.

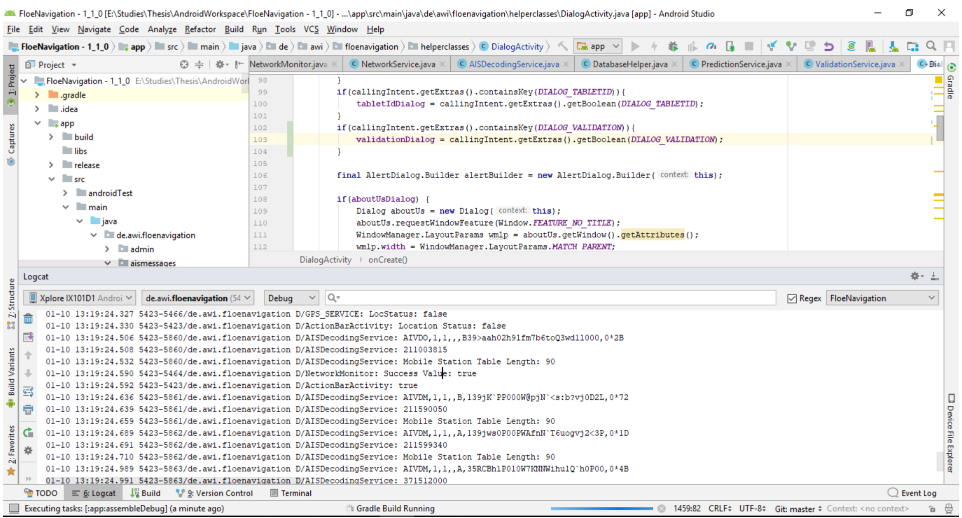

FIGURE 4.5. Logcat Window in Android Studio displaying the Logs from the tablet. **Insert better screenshot**

CHAPTER 5

FLOE NAVIGATION APP OVERVIEW

This section gives a brief description of the implemented Floe Navigation System. It will show how the Navigation System described in Chapter 6 is implemented and how the system looks like from the perspective of a User and Administrator. The Floe Navigation Android Application can be installed on any Android tablet. For detailed information, check the Floe Navigation User Guide and Floe Navigation Administrator Guide.

5.1 User Menu

This section describes how to use the Floe Navigation Application. It provides a basic description of the menus in the App for the User. The screenshots shown here are based on the default product configuration.

5.1.1 Dashboard

The Dashboard is the main screen of the App. It is the first screen that the user sees after launching the app. Using the Dashboard, the user can navigate to all the sections of the app as shown in figure 5.1.
The following icons are visible on the Dashboard:

- **Deployment:** Can be used to deploy a static station.
- **Sample/Measurement:** To take a Sample/Measurement on the Ice.
- **Waypoint:** Insert a waypoint on the Grid.
- **Grid:** Show a visual representation of the whole coordinate system.
- **Administrator:** For the administration of the App.

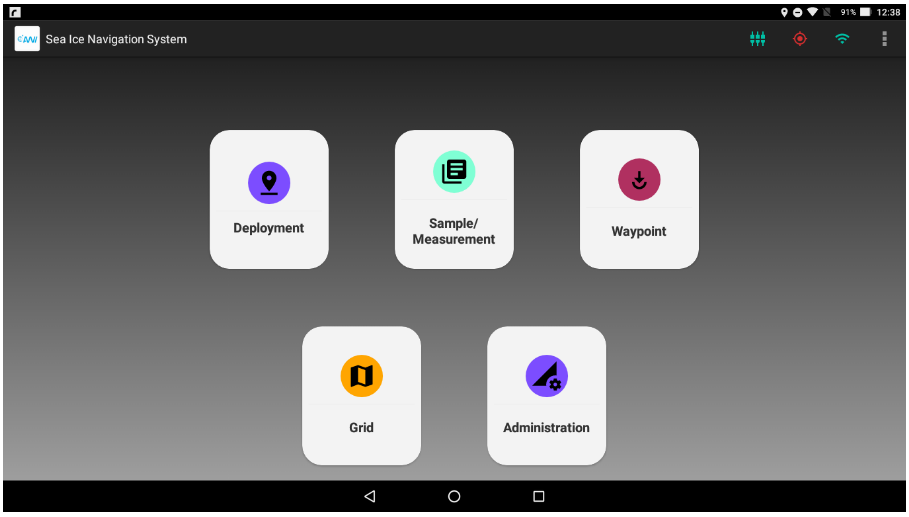

FIGURE 5.1. Dashboard as seen on Android Tablet.

5.1.2 Grid

The Grid is a visual representation of the coordinate system established on the sea ice. As shown in figure 5.2, the Grid shows all the stations and points of interest in a 100 km radius from the origin.

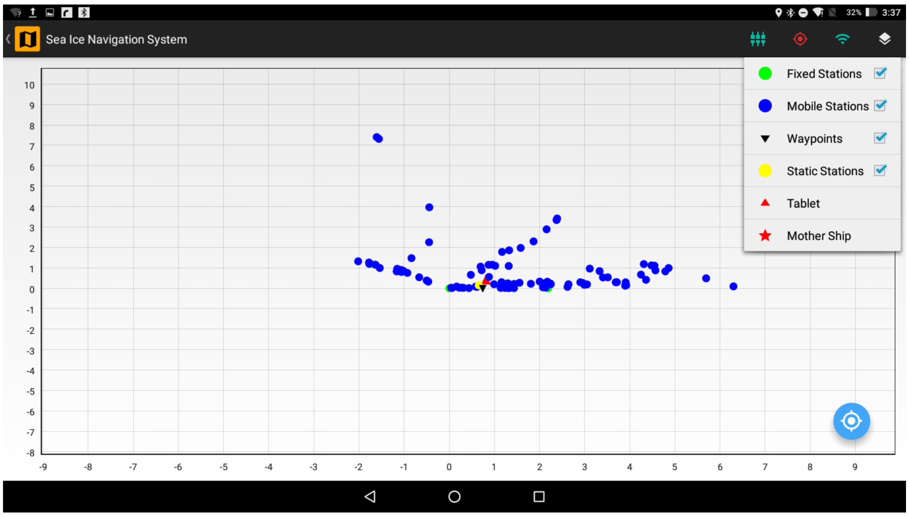

FIGURE 5.2. Visual Representation of the Coordinate System.

Table 5.1 shows the layers that are visible on the Grid by default along with their respective icons.

Layer	Icon
Fixed Station	Fixed Stations
Mobile Station	Mobile Stations
Waypoint	Waypoints
Static Stations	Static Stations
Own Position	Own Position
Mother Ship	Mother Ship

TABLE 5.1. Available Layers in Grid.

Tapping the icon of a station shows the relevant details of that station as shown in figure 5.3.

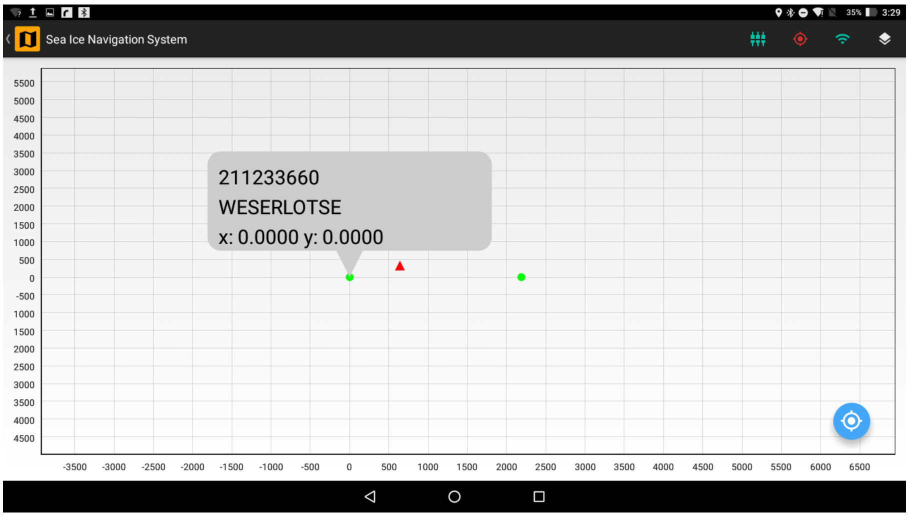

FIGURE 5.3. Details Box for a Station.

5.1.3 Deployment

As described in Chapter **(give reference here)** Static Stations are fixed points on the Sea Ice where any equipment or structure has been installed without an AIS Transponder. You can install a new Static Station by tapping on the Deployment button on the Main Dashboard which opens the Deployment screen. Static Stations once installed can only be deleted by an administrator. Figure 5.4 shows the Deployment screen.

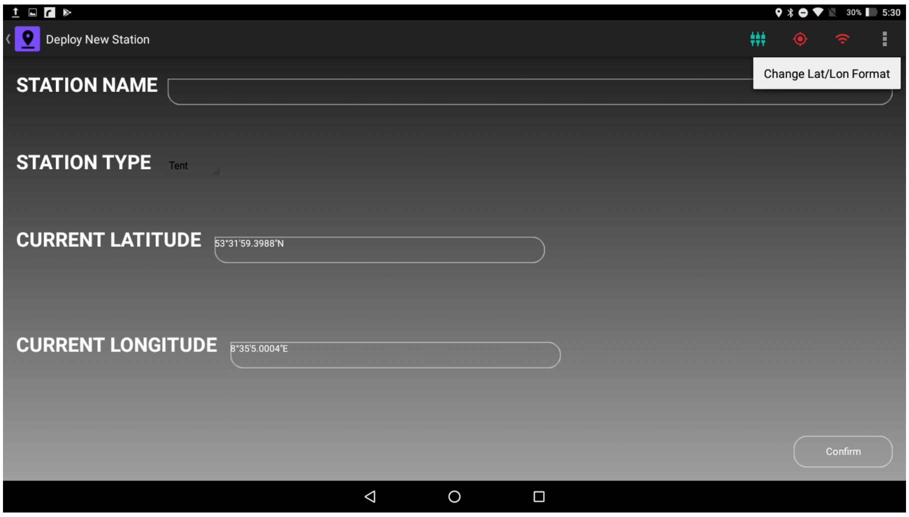

FIGURE 5.4. Deployment of a Static Station.

5.1.4 Waypoint

As described in Chapter **(give reference here)**, Waypoints are marked points of interest on the Sea Ice. Waypoints can be used to specify points along a track on the ice, or a single point where measurement can be taken in the future or it can also be used to marked danger zones or sensitive spots on the ice. Waypoints do not have an AIS data and hence are not used by the App to maintain the coordinate system.You can install a new Waypoint by tapping on the Waypoint button on the Main Dashboard which opens the Waypoint screen. Each Waypoint is identified by a unique label. Figure 5.5 shows the Waypoint installation screen.

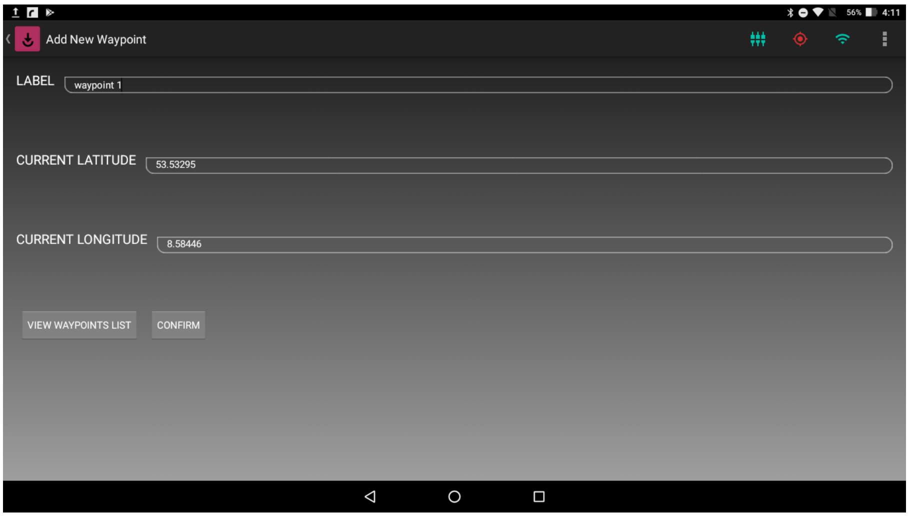

FIGURE 5.5. Installation of a Waypoint.

5.1.5 Sample/Measurement

Add Description after name and screenshots are updated. As described in Chapter **(give reference here)**, Waypoints are marked points of interest on the Sea Ice. Waypoints can be used to specify points along a track on the ice, or a single point where measurement can be taken in the future or it can also be used to marked danger zones or sensitive spots on the ice. Waypoints do not have an AIS data and hence are not used by the App to maintain the coordinate system.You can install a new Waypoint by tapping on the Waypoint button on the Main Dashboard which opens the Waypoint screen. Each Waypoint is identified by a unique label. Figure 5.6 shows the Waypoint installation screen.

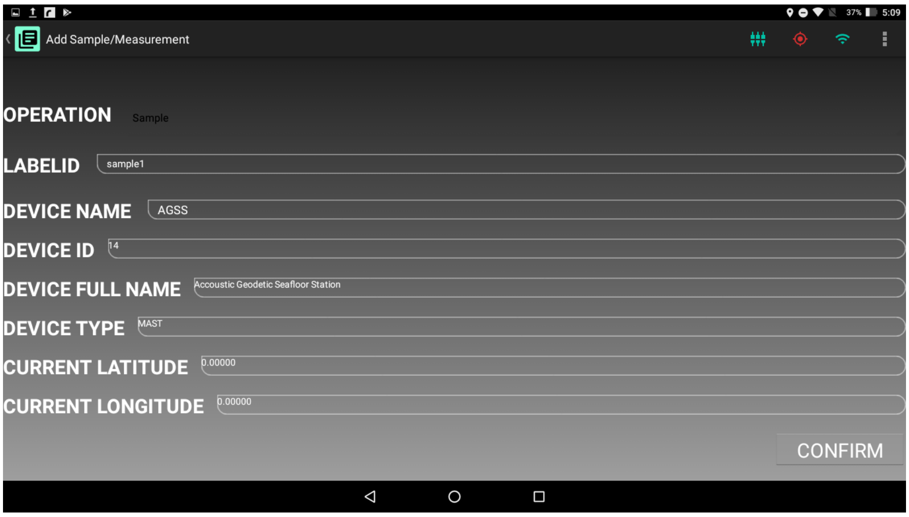

FIGURE 5.6. Installation of a Waypoint.

5.2 Admin Menu

This section describes how to administer the Floe Navigation Application. It provides a basic description of the menus in the App for the Administrator.

5.2.1 Admin Dashboard

The Admin Dashboard can be opened from the Main Dashboard of the Floe Navigation App. The Admin Dashboard can only be accessed with valid user credentials and it can be used to setup the coordinate system, synchronization and other admin tasks. Figure 5.7 shows the Admin Dashboard.

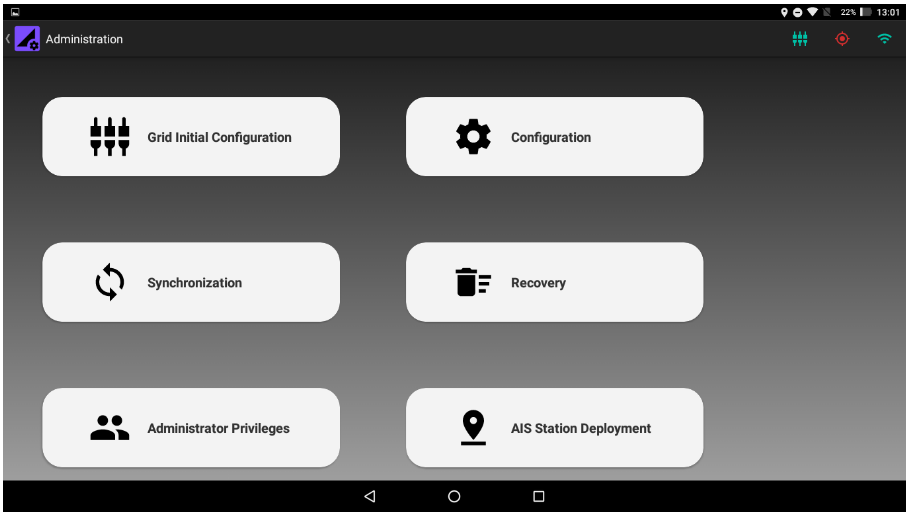

FIGURE 5.7. Admin Dashboard.

5.2.2 Grid Initial Configuration

As described in Chapter **Insert Chapter Label here** the Floe Navigation system needs at least two AIS Transponders installed as Fixed Stations on the Sea Ice to create its coordinate system. The Admin needs to install two Fixed Stations to run the Configuration setup. The setup runs for a specified time and creates a coordinate system when finished. Figure 5.8 shows a configuration setup in progress.

FIGURE 5.8. Grid Initial Configuration in progress.

5.2.3 Configuration

Certain important parameters can be configured by the admin which are used by the App for its background services and this can be done using the Configuration menu. Figure 5.9 shows the configuration parameters.

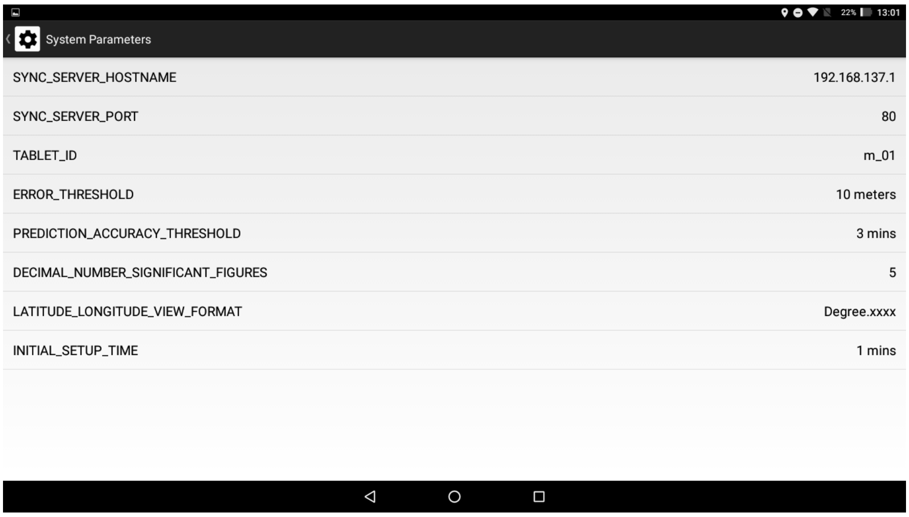

FIGURE 5.9. List of Configurable Parameters.

5.2.4 Synchronization

Synchronization process ensures that all the important data which is used to create and maintain the coordinate system remains the same in all the tablets. When the coordinate system has been established on one tablet; that tablet must be synchronized with the Sync Server and the data is pulled into other tablets to set up the coordinate system. This helps in maintaining a uniform coordinate system in all the tablets. The Device list which is used to take Sample/Measurement is also imported with the Synchronization process. Figure 5.10 shows the synchronization tool on the App. Figure 5.11 shows a running synchronization process.

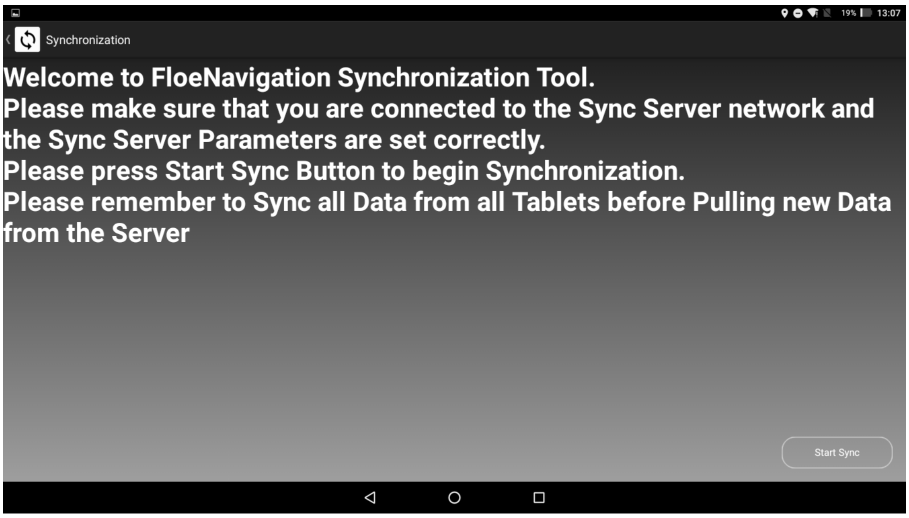

FIGURE 5.10. Synchronization Tool.

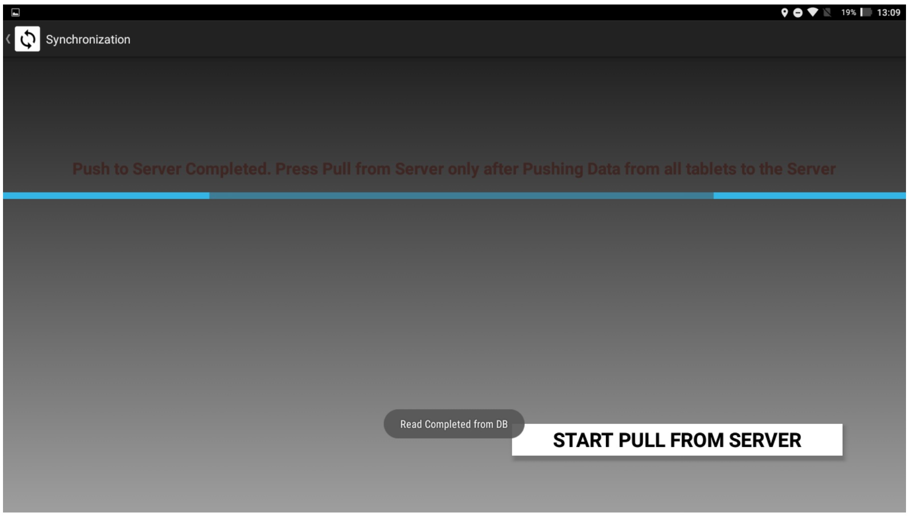

FIGURE 5.11. Synchronization in Progress.

5.2.5 Recovery

When a Fixed Station is no longer in use or if the Sea Ice breaks, the AIS Transponder on that position can be recovered and reused in another position. If a Fixed Station is recovered, it is no longer used to maintain the coordinate system by the app and the AIS transponder if it is powered on, will become a Mobile Station until it is reinstalled as a Fixed Station. Similarly, a Static Station can also be removed if it is no longer useful. Fixed Station and Static Stations can only be recovered by an Administrator of the Floe Navigation App. Figure 5.12 shows the recovery of a Fixed Station.

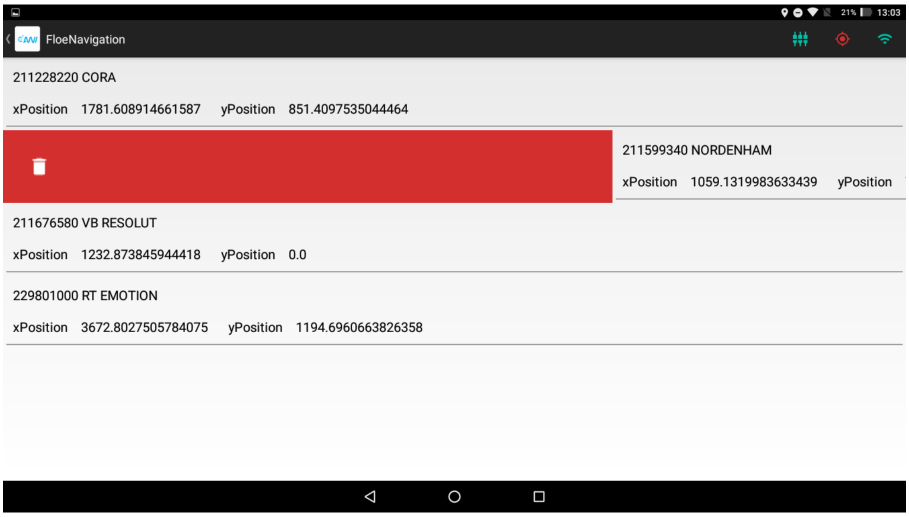

FIGURE 5.12. Recovery of a Station.

5.2.6 Administrator Privileges

Administrators can be added or removed using the Administrator Privileges Menu. Figure 5.13 shows the Administrator Privileges Menu.

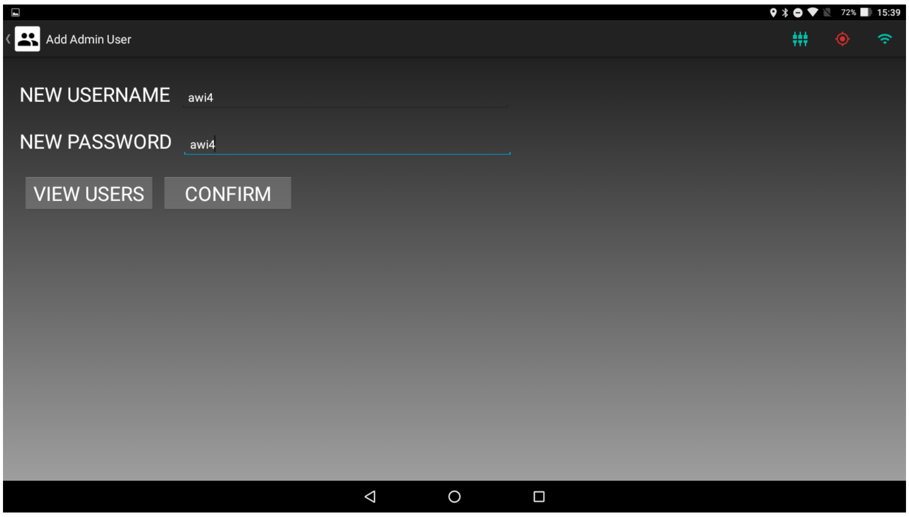

FIGURE 5.13. Creating a New Administrator.

5.2.7 AIS Station Deployment

New Fixed Stations can be deployed by the Administrators. Figure 5.14 shows the AIS Deployment Screen.

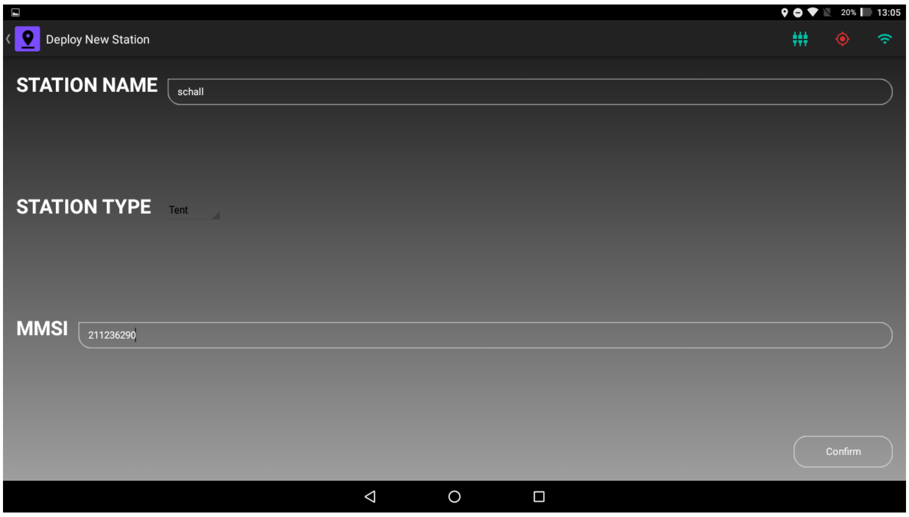

FIGURE 5.14. Deploying a new Fixed Station.

APPENDIX A

APPENDIX A

Begins an appendix

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