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Research Article

Development of mobile services for weather observation information

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Abstract: NCHMF and JICA team decided development of mobile services as an activity of the JICA Project. The mobile service system displays the data of Automatic Rain Gauge (ARG) stations, radars and meteorological satellites and the extreme weather warning messages disseminated from the system are aimed at users nationwide. The system is designed using modern technologies with high stability to meet the technical requirements of the project. The system's database is MongoDB, which is flexible in storing different data sizes. The user interfaces of both the website and mobile app are programmed using React (ReactJS and ReactNative). The system is designed with two servers connected in a cluster, so it has high stability. Alerts are delivered to users quickly using push notification technology, suitable for personal computers and iOS and Android mobile devices. The system is in line with the trend of Vietnamese people using mobile devices to monitor weather information today. Therefore, this will be an effective source of extreme weather warnings that VNMHA can use.

Keywords: Radar; Meteorological satellite; Weather observation information.

1. Introduction

In late years, disaster damages by severe weather increases rapidly in Vietnam. Especially heavy rain and the flood caused a serious situation for people's life. To prevent the serious damages weather Warnings and flood alerts must be quickly delivered to the people in the correspond area in addition to provision of understandable weather information. When we think about how to deliver information, mobile users are increasing day by day. More and more applications (apps) are continuously launching every day. In the year 2019, there were approximately 2.6 million Android apps and 2.2 million iOS apps available for users in the world. National Centre for Hydro-Meteorological Forecasting (NCHMF) and the Japan International Cooperation Agency (JICA) team considered the necessity to improve warning delivery and weather information provision and taking the opportunity of the mobile service trend. Then they decided on the development of mobile services as an activity of the JICA Project. The target information was observation data from weather radar, Automatic Rain Gauge (ARG), and satellite, in addition to forecast and warnings.

The development has been carried out mainly by Working Group 4 of the JICA Project and a contractor since December 2020. There were several processes, such as technical research, system design, prototyping and developing individual functions, functional test and verification, and comprehensive evaluation for operation. Then the development was mostly completed in December 2022 despite delay due to COVID-19.

2. Materials and Methods

2.1. Description of study area

The mobile service system displays the data of ARG stations, radars, and meteorological satellites. While ARG stations installed in the project are concentrated in the Northeast and North Central regions, radar and satellite images are spread throughout Vietnam. The extreme weather warning messages disseminated from the system are aimed at users nationwide. Therefore, the database in the system is designed to target the entire territory of Vietnam in the display. This is an advantage, i.e., there is no need to modify the system when the data from other ARG stations are provided for the system.

The system processes and displays four types of input data, i.e., observation data of weather radar, ARG and meteorological satellite, and extreme weather forecast and warnings. These data are quite diverse such as from real-time monitoring to forecast, from time series to grid form, and from coded to unstructured. A few software modules below the service layer have been built to ensure the integration and conversion of data to suit the system so that data can be displayed to users quickly and conveniently.

2.2. Development conditions

The system development process is related to several units in the Viet Nam Meteorological and Hydrological Administration (VNMHA). The roles of the units during the system development are as follows:

- Hydro-Meteorological Information and Data Center (HMIDC) is a centralized data and equipment management unit for the system. The unit advises on technical solutions so that the system can be connected to the existing information systems of the VNMHA.

- Aero Meteorological Observatory (AMO) is a unit that provides radar data and manages data of ARG stations used in the radar data calibration algorithm. The unit advises solutions on data display to suit users.

- NCHMF is the unit that provides extreme weather forecast and warning bulletins.

- Northeast and North central regional HMSs are units directly managing ARG stations located in the field.

The system was developed to provide operational services for quickly and conveniently receiving observation and warning information on mobile devices with different screen sizes and operating systems. The main requirements for the system are as follows:

- Timely data dissemination: observed data must be displayed in real-time, and dangerous weather warnings must be quickly distributed to users by data push technology.

- Easy access by widespread mobile users: the system must consist of a mobile website and mobile apps for iOS and Android devices with a friendly interface and easy-to-use concepts.

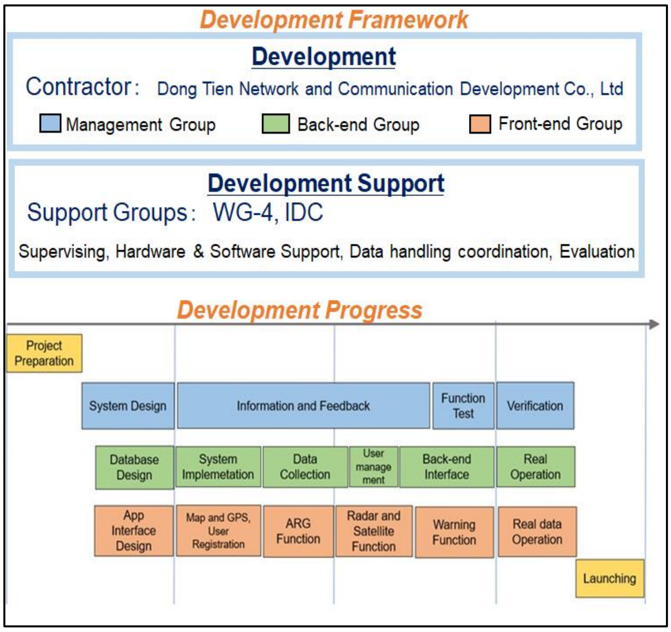


Figure 1. Mobile services system development diagram.

- Easily understandable visualization: it is required that data can be displayed in tabular, graph and map form, and station map and grid data must be displayed on top of the base map and be able to represent animation as well as perform operations to zoom in and out.

Based on the requirements, the system was developed under the collaboration framework shown in Figure 1.

2.3. Materials

Since the input data differs in format and data source, they need to be analyzed and processed separately.

2.3.1. Radar data

The input radar data are stored in NetCDF format [1]. Figure 2 shows an example of parameters of a data file in NetCDF format. This common format makes it convenient to share and store meteorological data.

```
dimensions:
        latitude = 1600 ;
        longitude = 1100 ;
        time = UNLIMITED ; // (1 currently)
variables:
        double latitude(latitude) ;
                latitude:units = "degrees_north" ;
                latitude:long_name = "latitude" ;
        double longitude(longitude) ;
                longitude:units = "degrees_east" ;
                longitude:long_name = "longitude" ;
        double time(time) ;
                time:units = "seconds since 1970-01-01 00:00:00.0 0:00" ;
                time:long_name = "verification time generated by wgrib2 function verftime()" ;
                time:reference_time = 1673595600. ;
                time:reference_time_type = 1 ;
                time:reference_date = "2023.01.13 07:40:00 UTC" ;
                time:reference_time_description = "analyses, reference date is fixed" ;
                time:time_step_setting = "auto" ;
                time:time_step = 0. ;
        float var0_1_200_surface(time, latitude, longitude) ;
                var0_1_200_surface:short_name = "var0_1_200_surface" ;
                var0_1_200_surface:long_name = "desc" ;
                var0_1_200_surface:level = "surface" ;
                var0_1_200_surface:units = "unit" ;

// global attributes:
                :Conventions = "COARDS" ;
                :History = "Fri Jan 13 14:55:41 2023: ncatted -a _FillValue,var0_1_200_surface,d,f,0.0 rdr_202301130740.nc\n",
                        "Fri Jan 13 14:55:41 2023: ncatted -a _FillValue,var0_1_200_surface,o,f,0.0 rdr_202301130740.nc\n",
                        "created by wgrib2" ;
                :GRIB2_grid_template = 0 ;
                :NCO = "netCDF Operators version 4.7.5 (Homepage = http://nco.sf.net, Code = http://github.com/nco/nco)" ;
```

Figure 2. Parameters of a radar data file in NetCDF format.

To display radar data (NetCDF format) into the website, we use a technique to convert this data to GeoTiff format [2], this format helps display radar on the website. We use a script module to download and convert data from NetCDF format to GeoTiff format.

2.3.2. ARG data

ARG data from stations are transmitted to a centralized server in text file format shown in Figure 3, with 2 frequencies of 10 minutes and 1 hour, each station has one data file equivalent to each frequency. The system has collected these data and put them into a decoding module to extract the corresponding rain values and put them into the database. During the processing, the total daily rainfall has been calculated by the system to display result statistics.

```
00010,6,14.20.00,13,01,2023,0,M02,2,B,0.0,2,X,12594,#15
00010,6,14.30.00,13,01,2023,0,M02,2,B,0.0,2,X,12594,#15
00010,6,14.40.00,13,01,2023,0,M02,2,B,0.0,2,X,12594,#15
00010,6,14.50.00,13,01,2023,0,M02,2,B,0.0,2,X,12594,#15
00010,6,15.00.00,13,01,2023,0,M02,2,B,0.0,2,X,12594,#15
00010,6,15.10.00,13,01,2023,0,M02,2,B,0.0,2,X,12594,#15
00010,6,15.20.00,13,01,2023,0,M02,2,B,0.0,2,X,12594,#15
00010,6,15.30.00,13,01,2023,0,M02,2,B,0.0,2,X,12594,#15
```

Figure 3. Data text transmitted from an ARG station.

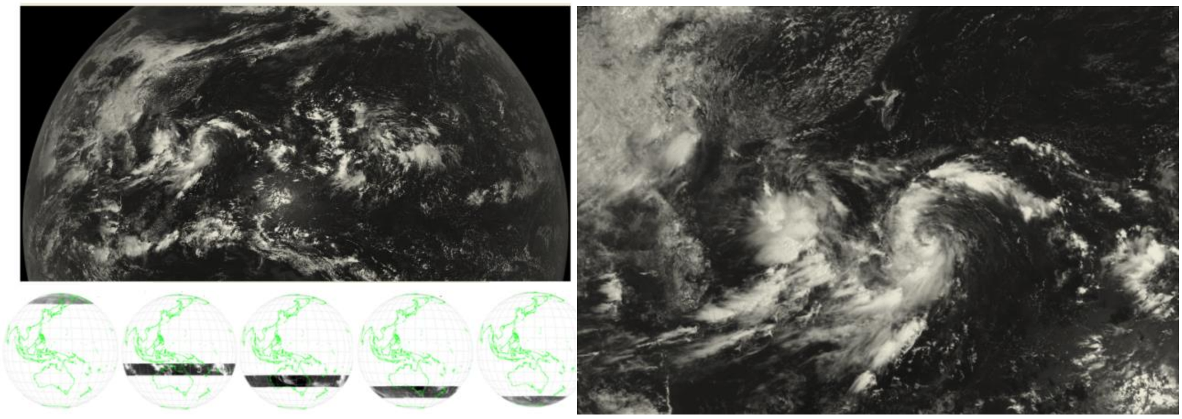
2.3.3. Satellite data

The satellite data used in the system are Himawari satellite data provided by the Japan Meteorological Agency (JMA). They are used at the VNMHA in several different formats shown in Table 1.

Table 1. Himawari Satellite data formats.

Data format	Data Source	Available at VNMHA in development progress
HSD	HimawariCloud	Yes
SATAID	HimawariCast	Yes
NetCDF	Central Data Hub	Not yet

HSD (Himawari Standard Data) format [3] is the original binary one provided through "HimawariCloud" which is a client-server network service operated by JMA. All other formats are converted from this format. Original data in HSD format are large in volume due to no clipping process. SATAID (Satellite Animation and Interactive Diagnosis) format is commonly used in desktop applications at the VNMHA. Data in SATAID format are provided to the VNMHA through "HimawariCast" which is a satellite broadcast system operated by JMA.



(a) **(b)**

Figure 4. Himawari satellite data: (a) HSD; (b) Data converted to Geotiff and clipped area.

The NetCDF format is a popular one for grid data worldwide. Therefore, the initial design of the system is to use input satellite data in NetCDF format. Another software module has been built to convert satellite data from HSD format to Geotiff format for display on the system. Figures 4 and 5 show the comparison between HSD and Geotiff formats in visual image, and the processing scheme of Himawari satellite data, respectively.

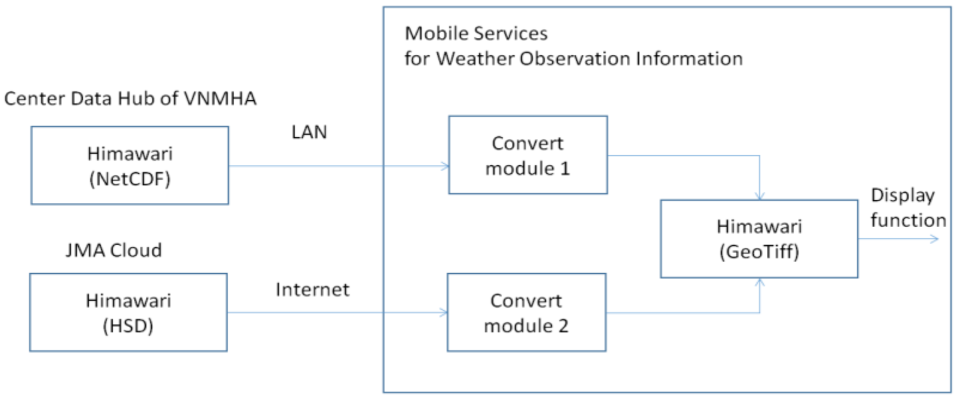


Figure 5. Processing scheme of Himawari satellite data in the system.

The system collects and processes two out of 16 bands of the Himawari satellite imagery, i.e., one visible band and one IR band. Because the system must rapidly provide local people with warnings at a high priority, other bands are not processed to reduce the system load.

2.3.4. Forecasts and warnings

Warnings provided through the system are generated based on two sources. The first source is created by local administrators registered on the website, and the second one is the extreme weather forecast and warning bulletins from NCHMF.

2.4. Methods

The system is designed using modern technologies, with high stability to meet the project's technical requirements. The system's database is MongoDB [4], which is flexible in storing different data sizes. Because it is stored as JSON [5], the system can easily insert the information as needed. The process to check compatibility when adding, deleting, or updating data for this type of database is quick and timesaving.

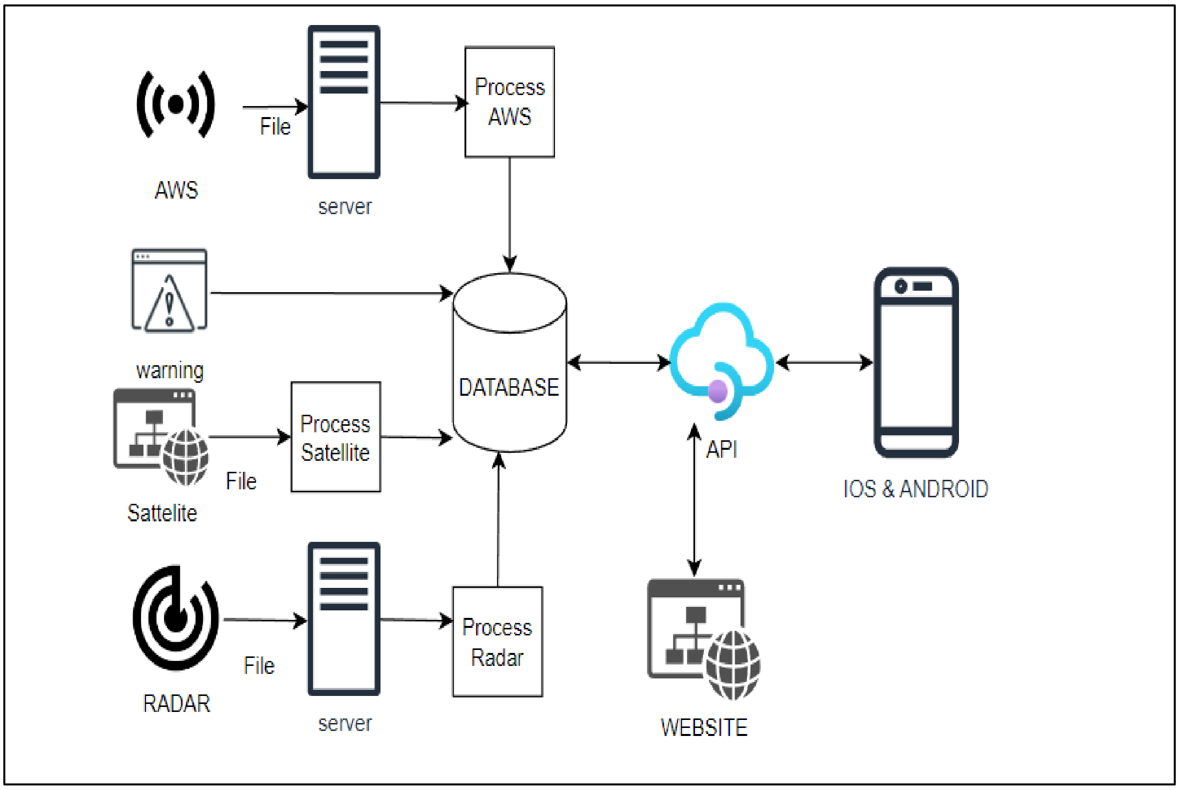


Figure 6. System functional diagram.

The system uses APIs to get data from the database provided to the website and mobile app as shown in Figure 6. The user interface of both the website and mobile app is programmed using React (ReactJS [6] and ReactNative [7]). This is a widely used framework today due to its many advantages such as flexibility, ease of maintenance due to modular architecture, high performance even with complex applications.

Two servers of the system (Worker Server 1 and 2) are connected and run Docker to form a cluster. The advantage of Docker Swarm is that it allows automatic routing and load balancing so that the application can operate with high stability. Figure 7 shows the system component based on two servers.

The system follows the user-friendly interface design concept. The system uses HTML5, CSS3, and JavaScript to move, resize, hide, and display elements based on the device. It is compatible with different operating systems and web browsers.

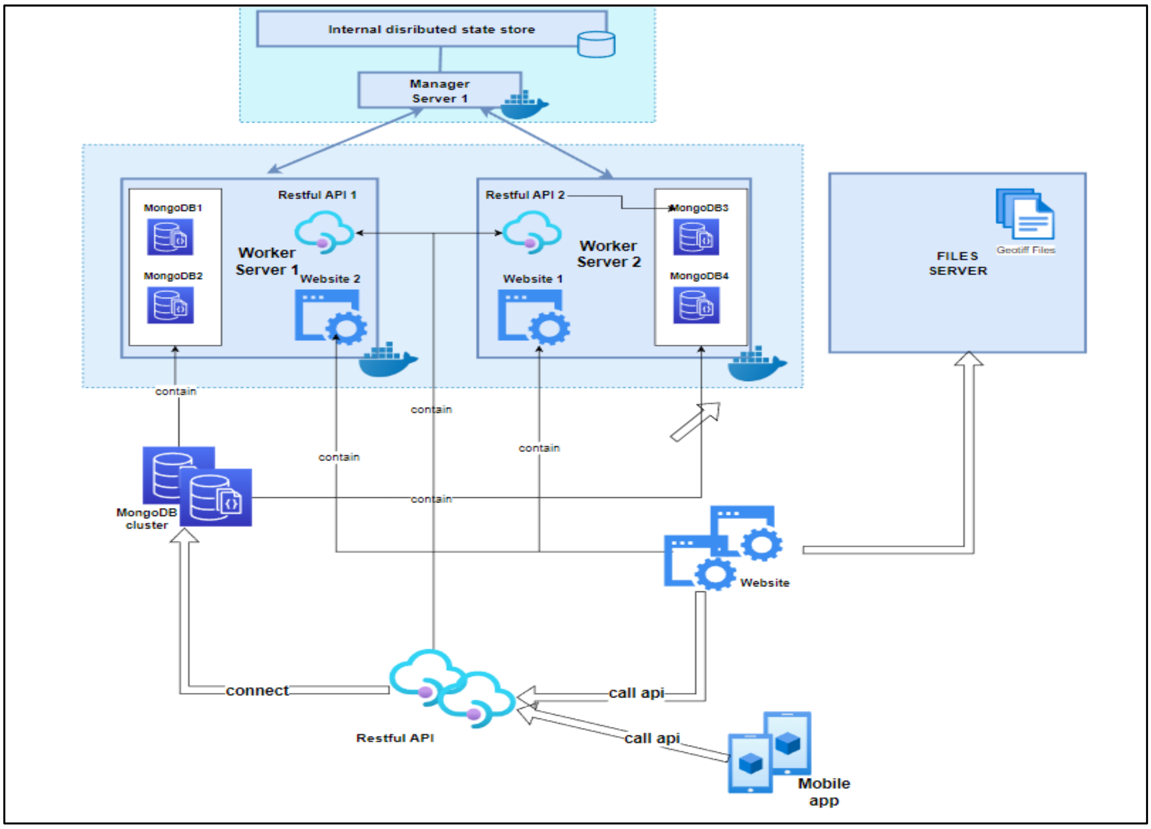


Figure 7. System component diagram.

3. Results and Discussion

3.1. ARG data display function

Rain data of ARG stations are automatically displayed as icons with numbers and colored according to warning scales. This makes it easy for users to track rain data during the day, and quickly identify areas with heavy rain, and can monitor the operating status of the station. Users can view detailed station information by pointing at the corresponding station icon. Precipitation data are displayed graphically at a frequency of 1 hour or 10 minutes. Figure 8 shows an example of ARG display.

The system also provides a detailed view of rainfall in the form of a table with a search function by a combination of station code, period, frequency, and total rainfall statistics, and warnings when the rainfall exceeds the threshold shown in Figure 9.

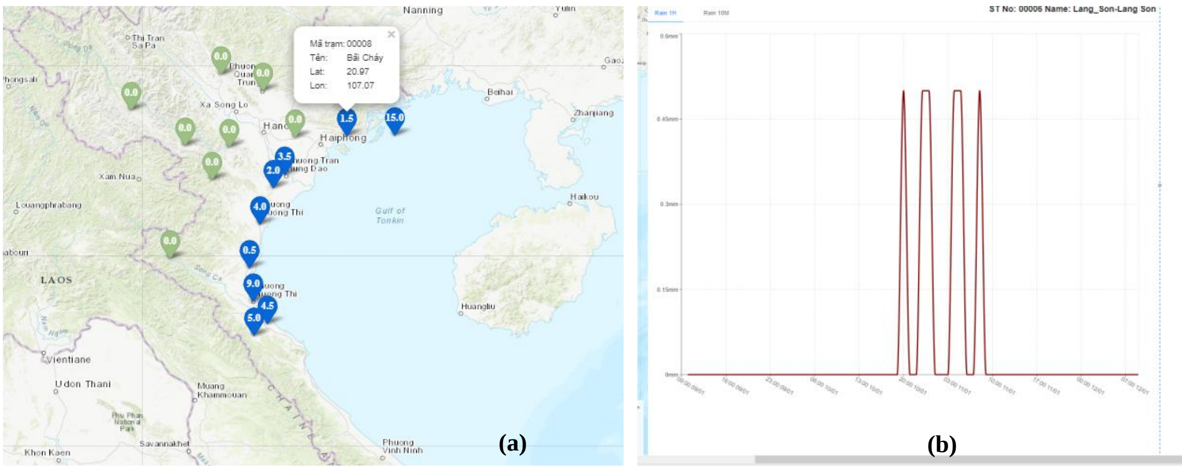
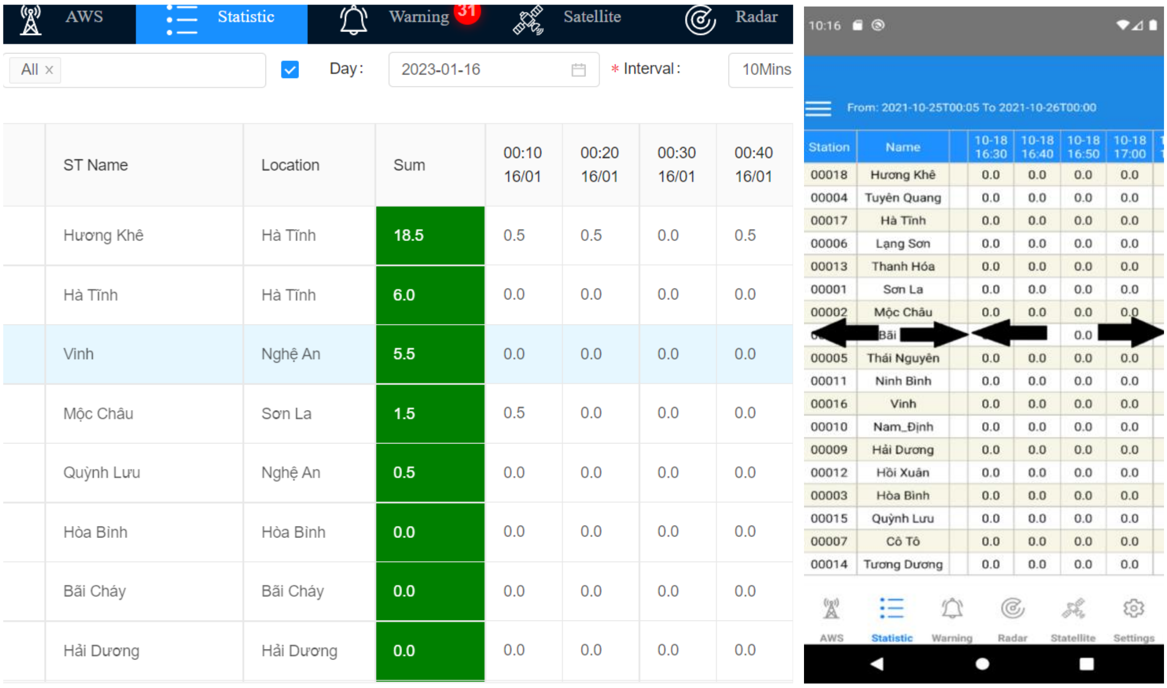


Figure 8. Precipitation display: (a) on the map; (b) graph mode.



(a) **(b)**

Figure 9. ARG statistics interface: (a) on the website; (b) on the mobile app.

3.2. Satellite data display function

The system provides a viewing function of a real-time satellite cloud image in GeoTiff format, which can determine the data value of each point on the map as shown in Figure 10. Users have a view of a series of animated images or a single image, which can overlay the radar layer and/or ARG layer.

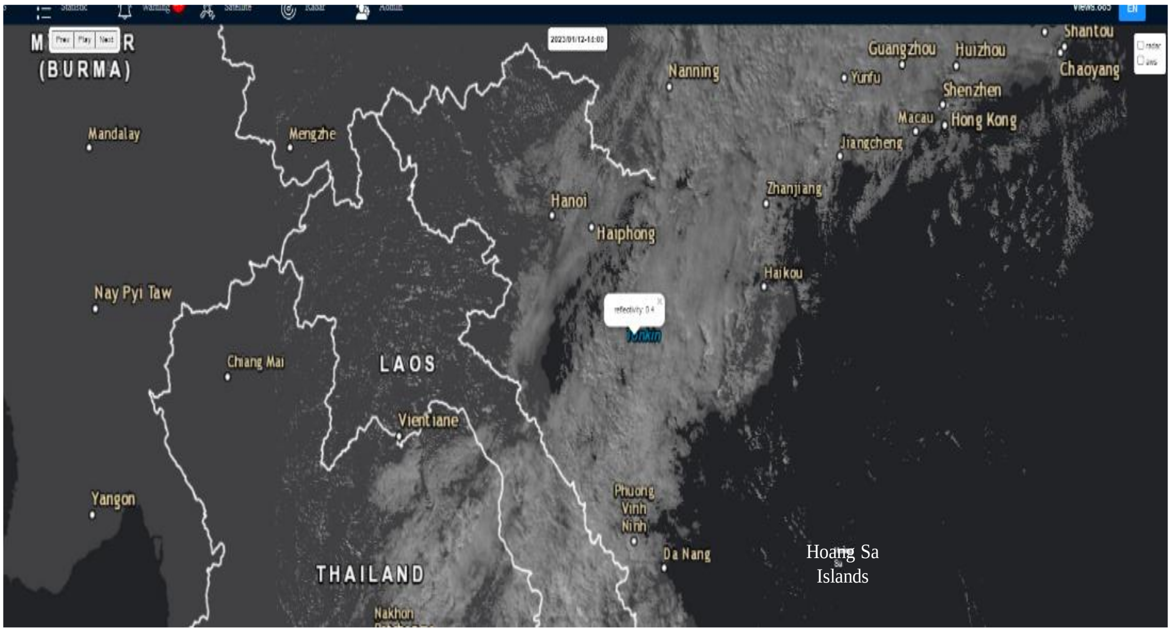


Figure 10. Himawari satellite image.

When in overlay mode, users can click a point to view both radar (estimated precipitation) and satellite (reflectivity) values and ARG stations which are automatically displayed as an icon with values and colors equivalent to the rain warning levels are easy to monitor as shown in Figure 11. Full-featured mobile app interface is similar to the mobile website.

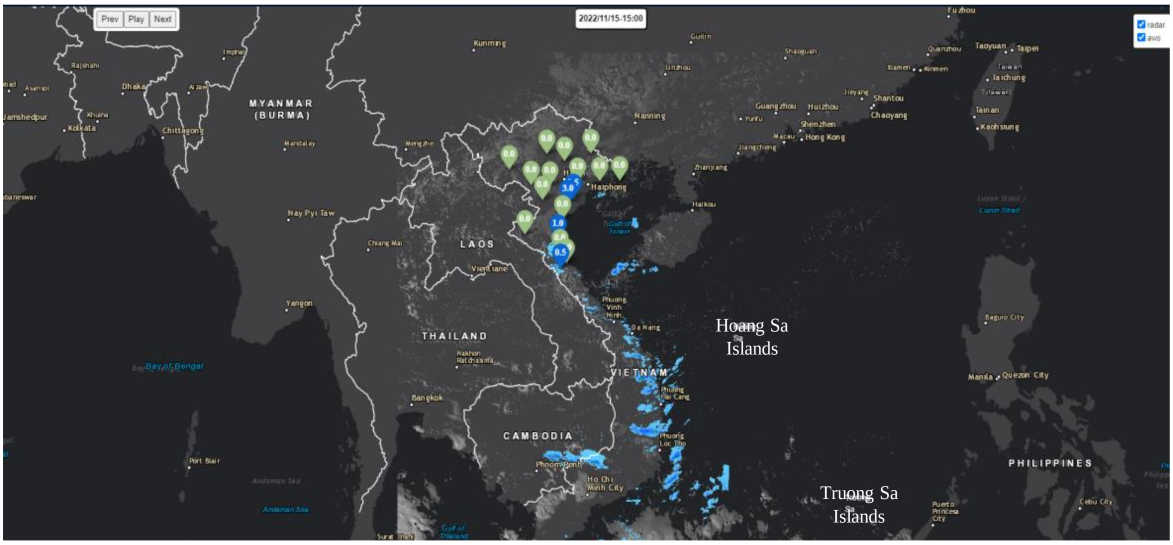


Figure 11. Overlay of ARG, radar and satellite.

3.3. Radar data display function

The system provides a viewing function of a real-time radar data in GeoTiff format shown in Figure 12, users can click on any point on the image to get the estimated rainfall value from the radar. Users have a loop view of images or individual images. The interface is capable of overlaying can overlay the satellite layer and/or ARG layer (on both the website and mobile app).

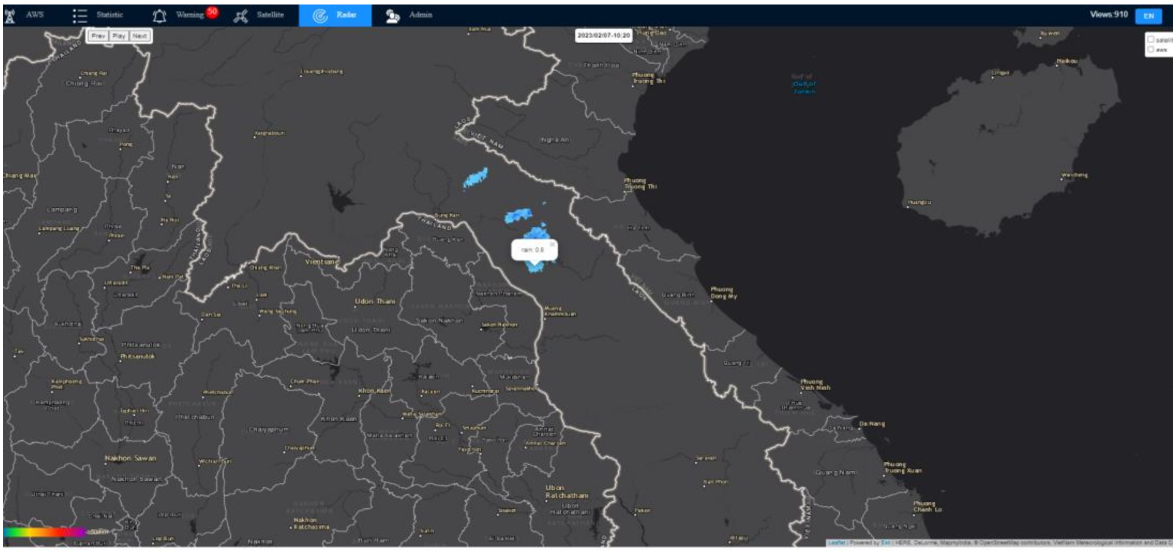


Figure 12. Radar data display.

When in overlay mode, Users click on a point to view both radar (estimated precipitation) and satellite (reflectivity) values, and ARG stations which are automatically displayed as icons with values and colors equivalent to the rain warning levels are easy to monitor, it is the same as Satellite Tab. Full-featured mobile app interface is similar to the mobile website.

3.4. Real-time warning function

The system provides a warning function to users by data push technology. Users will receive a warning when accessing the website or the mobile App. The interface displays the number of available warning messages and can view the content of the warning messages in real-time shown in Figure 13.

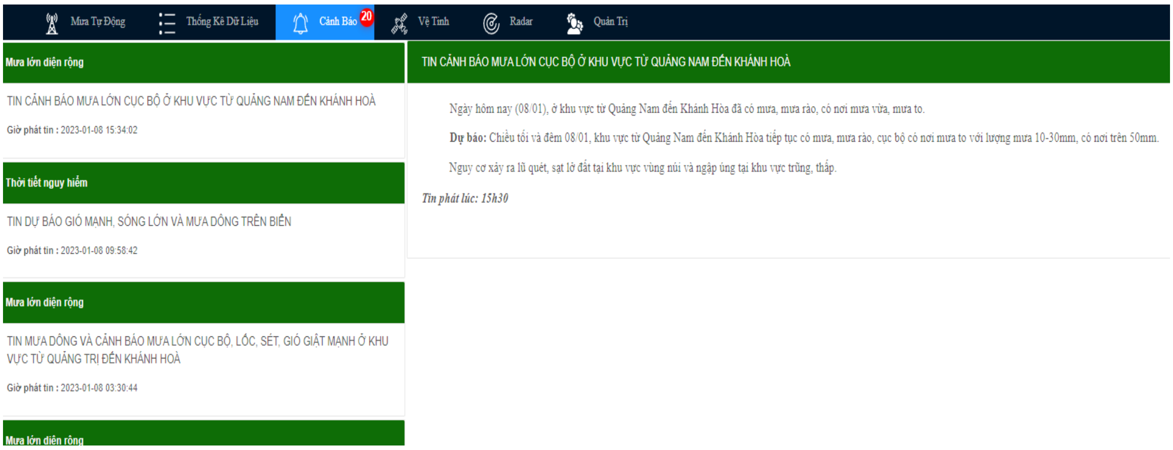


Figure 13. Real-time warning function on the website.

There are 2 types of users. Regular users only can view and receive alert messages. Administrative users can create, edit, and post warning-bulletin. The administrative interface is fully functional like a regular text editor shown in Figure 14, so users can easily use it.

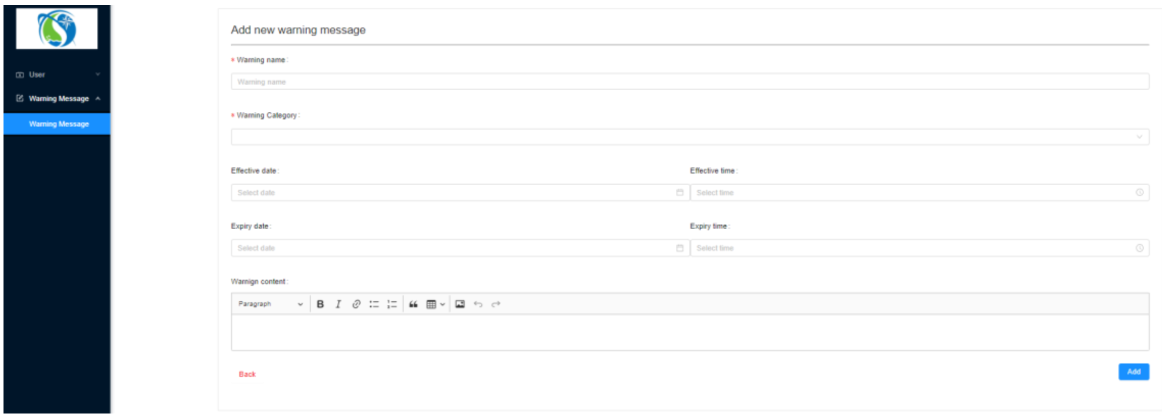


Figure 14. Administrative interface for creating bulletins on the website.

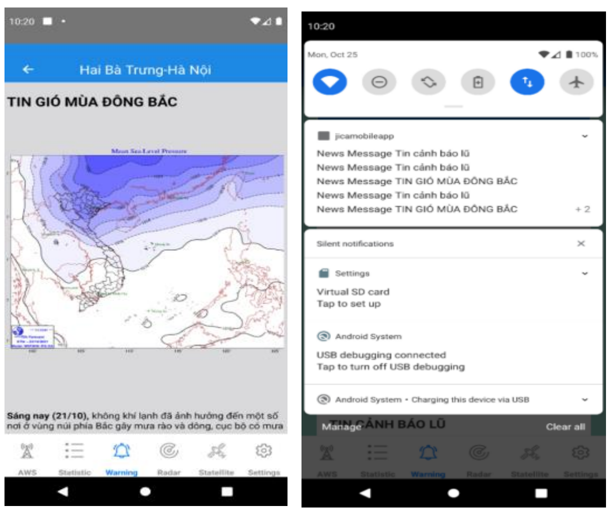


Figure 15. Real-time warning function on the mobile app.

The mobile app has information according to the registered user's location shown in Figure 15. Users can add multiple locations to receive warning messages related to the locations when there is a new dangerous weather warning.

The weather observation information app is available in both Apple Store and Google Play shown in Figure 16.

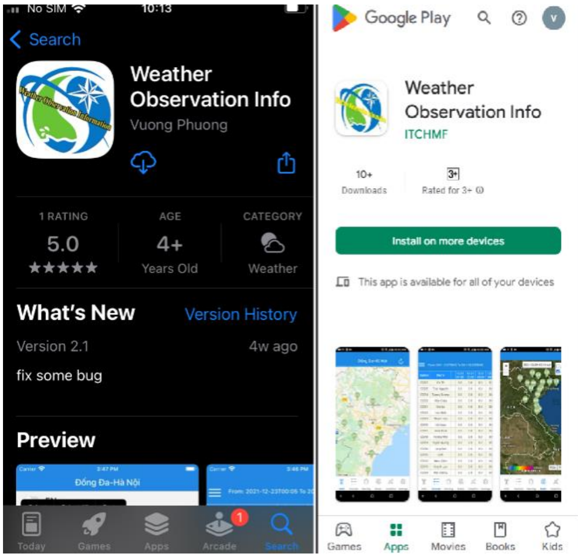


Figure 16. Weather observation information app in both Apple Store and Google Play.

4. Further consideration

The system has been fully deployed under the HMIDC management. Most of the system's modules operate automatically, except for the module that enters the warning message manually for the administrator. However, due to the requirement to notify users in real-time in dangerous weather conditions, a regular data monitoring process for the system's stable operation by the center's administrators is still required.

Since the system is designed to display rain data from automatic stations throughout Vietnam, it is possible to expand the display of data from other rain gauges. In addition, additional layers of satellite imagery can be added to the system to provide the user with more information.

Both monitoring data and warning information are provided in real-time allowing users to receive accurate and fast weather information. However, the volume of radar and satellite image data is relatively large, therefore some low-capability devices may have slow data display.

5. Conclusions

The technical report presented the methods used in the development of mobile services for weather observation information and the results of the development.

The mobile services consist of a mobile web site and a mobile application. They are running on two servers connected in a cluster to realize high stability and accessibility. Push notification technology and database-oriented APIs are introduced to quickly deliver alerts to users, whatever they use any devices such as personal computers, tablet, and iOS and Android mobile phones. Therefore, this will be an effective source of extreme weather warnings that VNMHA can use.

The following user-friendly functions have been developed.

- Rain data of ARG stations are automatically displayed as icons with numbers and colored according to warning scales. The system also provides a detailed view function of rainfall in the form of a table with a search function by a combination of station code, period, frequency, and total rainfall statistics, and warnings when the rainfall exceeds the threshold.

- The system provides a viewing function of a real-time satellite cloud image, which can determine the data value of each point on the map.

- The system provides a viewing function of real-time radar data; users can click on any point on the image to get the estimated rainfall value from the radar. The interface can overlay the satellite layer and/or ARG layer on both the website and mobile app.

- The system provides a warning function to users by data push technology. Users will receive a warning when accessing the website or the mobile app.

Author Contributions: Analysis and writing–original draft preparation: H.I., N.V.M., V.M.P., N.V.H.; writing–review and editing: P.V.T.N., H.I.; All authors have read and agreed to the published version.

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Conflicts of Interest: The authors declare no conflict of interest.

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