Design and Implementation of an Android Mobile Interference Management APP for Radio Telescope Stations (Postprint)

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Abstract

Radio monitoring demonstrates that interference signals produced by mobile phone-to-base station communications can impact radio astronomy observational data. To mitigate radio frequency interference (RFI), astronomers have proposed radio management strategies including shielding electronic equipment within stations and establishing radio quiet zones. Mobile phone signals, in particular, are challenging to monitor and manage due to their inherent mobility and substantial user base. Nevertheless, activating airplane mode or powering off mobile devices can significantly reduce RFI. Building upon this principle, this paper presents the design and development of an Android-based mobile phone interference management application that employs positioning technology to automatically detect whether a device is located within a radio quiet zone, thereby prompting users to manage their devices appropriately and logging user actions within these zones. Experimental results indicate that when users are situated in radio quiet zones, the application can proactively remind them to enable airplane mode or shut down their devices, effectively diminishing the influence of mobile phone signals on astronomical observational data.

Full Text

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Abstract: Radio monitoring demonstrates that interference signals generated by mobile phone communication with base stations can affect radio astronomical observation data. To mitigate radio frequency interference (RFI), astronomers have proposed management measures such as shielding electronic equipment within stations and establishing radio quiet zones. However, mobile phone signals are particularly challenging to monitor and manage due to their mobility and vast numbers. Fortunately, enabling airplane mode or powering off mobile phones can effectively reduce RF interference. Based on this principle, this paper designs and develops an Android-based Mobile Interference Management APP (MIMA) that utilizes positioning technology to automatically determine whether a phone is located within a radio quiet zone, reminds users to manage their devices appropriately, and records user operations within the quiet zone. Test results demonstrate that when users enter radio quiet zones, the APP can proactively remind them to enable airplane mode or shut down their phones, thereby effectively reducing the impact of mobile signals on astronomical observation data.

Keywords: Mobile interference management APP; Radio astronomical observation; Radio frequency interference; Radio quiet zone

The increasing use of fixed electronic devices (such as base stations, computers, and routers) [1] and mobile electronic devices (such as mobile phones, laptops, and cameras) [2] has led to increasingly severe radio frequency interference at radio astronomy stations. While signals from fixed electronic equipment can be suppressed or eliminated through shielding and other technical means according to RFI management regulations [3], signals from mobile electronic devices pose significant challenges due to difficulties in real-time monitoring and control. Mobile phone signals are particularly problematic given their mobility and enormous user base.

When users operate mobile phones near radio telescopes, various signals—including communication signals between phones and base stations, mobile hotspot signals, signals from phones searching for base stations, and transient signals generated during power-on/off events [2,4]—can impact astronomical observation data. According to Ministry of Industry and Information Technology statistics, China had 1.57 billion mobile phone users in 2018[1], while FAST alone received 5.13 million visitors in the first half of 2018[2]. Without effective control measures for visitors' mobile phones, the scientific effectiveness of radio telescopes would be severely compromised. Current solutions for managing mobile phone interference include establishing radio quiet zones, setting up warning signs, and using wireless detectors to identify phones [3]. However, these approaches have notable limitations: manually managing stored phones increases operational costs; if phone storage is not mandatory, users may forget to enable airplane mode or power off; and the limited number of warning signs yields minimal effectiveness. Evidently, existing methods cannot actively, real-time, and effectively manage mobile phones.

To address these challenges, this paper designs and develops an Android-based

Mobile Interference Management APP (MIMA). When users enter areas near telescopes, such as radio quiet zones, the phone vibrates and rings to remind users to enable airplane mode or shut down, thereby reducing the impact of mobile signals on radio astronomical observation data. The remainder of this paper is organized as follows: Section 1 describes system functional requirements; Sections 2, 3, and 4 elaborate on system design, implementation, and testing, respectively; and Section 5 provides a summary and discussion.

1 Functional Requirements

The design objective is to create an APP that helps mobile phone users actively and intelligently manage their device status within radio telescope radio quiet zones. Functional requirements include: (1) Proactively reminding users to manage their phones when entering a quiet zone; (2) Notifying users to restore normal communication when leaving the quiet zone; (3) Featuring both server and client components; (4) Storing initialization configuration information on the server, which MIMA automatically loads upon startup; (5) Recording user operations (enabling/disabling airplane mode or powering on/off) within quiet zones and uploading these records to the server; (6) Supporting multiple positioning methods including GPS, base station, and third-party positioning; (7) Managing multiple astronomical stations simultaneously; and (8) Including station management functions with administrator oversight.

2 System Design

A well-designed system ensures that MIMA is extensible, portable, and maintainable. This section elaborates on design philosophy, architecture design, and process design.

2.1 Design Philosophy

Radio quiet zones (or electromagnetic wave quiet zones) at domestic and international radio astronomy stations are established based on factors including radio telescope antenna aperture, frequency, site electromagnetic environment, terrain characteristics, and local regulations. Consequently, different stations have varying hierarchical ranges and naming conventions for radio quiet zones, though most adopt a three-tier structure with progressively relaxed requirements from inner to outer zones [5,6]. For example, FAST' s three tiers correspond to radii of 5 km, 10 km, and 30 km. QTT, leveraging terrain features, divides its radio quiet zone into a rectangular core area (2.5 km $\times$ 4 km) and restricted area (10 km $\times$ 15 km), plus a coordination zone with a 30 km radius. To determine the positional relationship between users and radio telescopes, the spherical distance formula [7] (1) calculates the distance between the phone and telescope to identify the user' s zone. Reminder methods vary by zone: in the coordination zone, MIMA displays a dialog with ringtone and vibration (10-second reminder, repeated twice); in the restricted zone (if the user does not leave), a 15-second reminder maximum twice; and in the core zone, a 20-second reminder once.

$$D = R \cdot \arccos[\cos\beta_{u1} \cdot \cos\beta_{t1} \cdot \cos(\alpha_{u1} - \alpha_{t1}) + \sin\beta_{u1} \cdot \sin\beta_{t1}] \quad (1)$$

where points 1 and t represent two coordinates on Earth $(\alpha_{t1}, \beta_{t1})$ and $(\alpha_{u1}, \beta_{u1})$, D is the distance between the points, and R is Earth' s radius.

Investigation revealed that most astronomical institutions operate multiple stations. MIMA can manage multiple stations simultaneously by combining mobile positioning technology with the spherical distance formula to identify the nearest radio telescope to the user, calculate the distance, determine whether the user is within a radio quiet zone, and issue appropriate reminders.

2.2 Architecture Design

The system architecture comprises a three-layer MVC client architecture and a four-layer hierarchical server architecture. These architectures enhance intermodule coupling, reduce intra-module cohesion, ensure standardized interface definitions between system layers, and provide extensibility, portability, and maintainability [8].

2.2.1 Client Architecture Design The client architecture employs a three-layer MVC structure. [Figure 1: see original paper] illustrates the client components: user layer, application layer, and storage layer. The user layer provides the interface for viewing and interaction, displaying the distance between the user and radio telescope, feeding back missing or incorrect telescope configuration information to administrators, and providing quick access to GPS or airplane mode settings. The application layer forms the client core, addressing functional requirements from Section 1 through: (1) Assigning different priorities to positioning methods (GPS, base station, and third-party positioning such as Baidu Android SDK) based on power and data consumption (detailed in); (2) Reminding users to enable GPS for location determination when base station signals are poor or absent, GPS is disabled, and airplane mode is not active; and (3) Continuing positioning, data management, distance calculation, network transmission, and process management after interface exit. The storage layer preserves location information, intermediate results, and configuration data. SQLite stores radio telescope coordinates, quiet zone ranges and levels, and user operation records. The telescope configuration table includes fields for telescope ID, name, quiet zone range and level, while the user operation record table includes user ID, airplane mode status, power status, distance, phone serial number, and operation timestamps.

2.2.2 Server Architecture Design The server architecture utilizes a four-layer hierarchical structure comprising user layer, logic layer, data layer, and storage layer (see [Figure 2: see original paper]), enabling storage and query of mobile user operation records from MIMA. The user layer displays and searches operation records. The logic layer manages request distribution from the user layer and returns data from the storage layer. The data layer provides interfaces for data access and network protocols to complete data retrieval. The storage layer preserves mobile user operation records and administrator operation logs.

2.3 Design Process

[Figure 3: see original paper] illustrates the MIMA system design flow, encompassing initialization configuration, distance calculation between users and radio telescopes, identification of the nearest telescope, determination of whether the user is within a radio quiet zone, decision-making regarding airplane mode or shutdown, and final upload of user operation records to the server.

3 System Implementation

System implementation includes initialization, functional implementation, system testing, and interference result comparison, ensuring MIMA can proactively and intelligently enable airplane mode or shutdown within radio quiet zones, record user operations, and upload client operation records to the server.

3.1 Initialization

System initialization comprises configuration information initialization and positioning initialization. Configuration data is stored in JSON key-value pairs. Initialization of three positioning methods (GPS, base station, and third-party) obtains user coordinates. Baidu Android SDK initialization requires importing jar/so packages, adding development keys and permissions, and referencing global variables and initialization functions during application startup. Base station positioning initialization involves importing jar/so packages, adding permissions, and calling initialization functions to obtain coordinates and location information. GPS positioning initialization similarly requires importing jar/so packages and adding permissions.

3.2 Functional Module Implementation

The client' s MVC architecture separates the front-end interface from back-end services. The development environment is Android Studio, with the interface built using JAVA+XML and back-end services developed in JAVA. [Figure 4: see original paper] presents the client functional module class diagram. The interface class MIMAFront displays the user-telescope distance, formatted to two decimal places. The back-end service forms the client core; after interface exit, the BackService class depends on JudgeDis, KLService, and ShowDiag classes for positioning, calculation, judgment, and reminders. The KLService process management class ensures BackService maintains normal operation, while JudgeDis depends on initialization configuration (InitConInfo class) and mobile positioning (Location class) to determine user-telescope positional relationships. The ShowDiag class displays reminder dialogs when users enter quiet zones.

The server user layer is developed using HTML, CSS, and JavaScript, while the logic, data, and storage layers use JAVA. The BehRecSerImpl class inherits database operations from DBUtil to obtain model data. [Figure 5: see original paper] shows the server module class diagram. BehRecSerImpl instantiates interface functions getPageSetting(), getAll(), etc., from BehRecSer. The PageSetting class, which BehRecSerImpl depends on, manages basic page settings: pageSize defines entries per page, while currentPage, rowCount, and pageCount represent current page, total entries, and total pages, respectively. startIndex and endIndex denote first and last pages. The Page class, part of PageSetting, displays front-end page information.

4 System Testing

System testing includes functional testing and results comparison. Functional testing verifies APP reminders for phone management within quiet zones, while results comparison examines signal strength differences between normal operation and airplane mode.

4.1 Functional Testing

After APP installation, the system obtains user coordinates through GPS, base station, and Android SDK positioning, calculates user-telescope distance using spherical distance formula (1), identifies the nearest telescope, and displays data as shown in Figure 6: see original paper. When users enter radio quiet zones, a reminder dialog appears (Figure 6: see original paper), allowing users to tap the "Airplane Mode Settings" button to access the airplane mode interface (Figure 6: see original paper). Simultaneously, the server stores user operations from MIMA, enabling administrators to view or search operation records within quiet zones.

4.2 Results Comparison

Testing of airplane mode on/off revealed that normal operation generates signals searching for 2G, 3G, and 4G base stations to verify communication status, as shown in Figure 7: see original paper. After enabling airplane mode, phones cease generating search signals, as demonstrated in Figure 7: see original paper. Therefore, MIMA effectively manages mobile-generated signals, reducing their detrimental impact on radio telescope astronomical observations.

5 Summary and Discussion

Electronic device signals affect radio telescope observation data quality, and such signals are difficult to monitor, track, and manage in real time, particularly those from mobile phones carried by users near radio quiet zones. This paper designs and develops an Android-based MIMA that proactively reminds users to enable airplane mode or power off when entering quiet zones, thereby reducing adverse effects on radio astronomical observations. Compared to other interference suppression methods, this approach offers several advantages: (1) Lower economic cost compared to deploying numerous warning signs; (2) Friendly mobile reminders that educate visitors about the hazards of mobile electronic devices to radio astronomy; and (3) A complementary approach to existing RFI management regulations.

A current limitation is that testing has been conducted only on the Android platform; iOS platform development remains incomplete and requires further development to achieve comprehensive smartphone platform management.

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Note: Figure translations are in progress. See original paper for figures.