Software Design Document

——ZenSleep

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Software Design Document

1. **Introduction**

   1.1 Project Background

   According to the 2022 National Depression Blue Book, more than 95 million people in China suffer from depression. The Lancet and the World Psychiatric Association released a joint report stating that 5% of adults worldwide suffer from depression each year, and most patients with depression are not diagnosed or treated. In order to meet the challenges of depression patients around the world, this project plans to design a depression screening and regulation system based on sleep EEG signal analysis and brainwave music generation, aiming to improve the diagnostic accuracy of depression and accelerate the patient's recovery process. The system can not only identify depressive symptoms, but also monitor and improve the patient's sleep quality in real time, with the characteristics of high precision, high efficiency and high user-friendliness.

   Based on the characteristics of sleep EEG signals being non-invasive, easy to obtain and having high temporal resolution, this project will use an attention-based multi-channel EEG signal sleep staging method (AMCSleepNet) to make full use of the spatial and frequency domain characteristics of sleep signals to improve the accuracy of sleep staging. At the same time, a depression screening method is developed based on the deep residual network (PC-DRN) model architecture with pyramid convolution layers. This model can extract multi-scale and multi-band feature information through its unique pyramid convolution structure, thereby enhancing the accuracy of depression screening. Compared with traditional machine learning methods, this combination can more accurately perform sleep staging and depression screening. In addition, based on the scale-free characteristics of the amplitude of EEG signals and the distribution of pitch in music, this project proposes a scale-free brainwave music generation method based on single-channel EEG data, and uses actual EEG signals for music generation. This method not only faithfully reflects the detailed information of the waveform, but also retains the original scale-free nature of the signal. Based on this, this project develops a corresponding real-time brainwave music system to provide users with real-time feedback and relieve depression symptoms through music therapy.

   1.2 Project Concept

   ZenSleep is committed to helping users improve their sleep quality and enhance their quality of life through the fusion of technology .

   This project was tested with various public data sets to verify its generalization performance in different populations, and parameters were adjusted and optimized continuously, and the front-end and back-end codes were integrated to improve the accuracy and reliability of the system. Finally, we connected the EEG acquisition equipment to the computer to build an integrated depression diagnosis system that integrates signal acquisition, processing and classification, result output, and music regulation.

2. **Requirements Specification**
   2.1 Project Opportunities
       2.1.1   Market gaps

   At present, there is a lack of a sleep aid app in the market that deeply integrates technology and Zen ideas. ZenSleep fills this gap by offering users a new sleep and relaxation experience.

       2.1.2   Strong user demand

   A large number of users are eager for an app that can not only improve the quality of sleep, but also provide spiritual support. ZenSleep's comprehensive features and community support fit that need.

       2.1.3   The technical conditions are ripe

   The maturity of mobile application development technology, sensor technology and data analysis technology provides technical support for the development and function realization of ZenSleep.

   2.2 Marketing Overview

   Based on the current status of the industry, we divide target users into three types: C-end users, H -end users and B -end users . B -end users are professional medical device manufacturers and are also the main target users of this product. C -end users , as direct users and the main beneficiary group, are patients and potential patients who have been diagnosed with depression. H -end users are professional medical institutions, mainly hospitals. Marketing is mainly carried out through the following methods:

   A.   Subscription Fees

   In order to meet the needs of different target groups, we adopt a flexible monthly subscription fee model to provide customers with continuous value and service. We will provide two subscription methods: basic version and advanced version, and different groups can choose according to their needs. The basic version subscription includes general diagnostic and analysis functions, such as system access, standard data analysis and regular updates. The advanced version subscription is more personalized, providing advanced functions such as customized analysis and priority customer support.

   B.   Sales share

   Cooperate with professional medical device manufacturers to bundle this system with professional medical devices for sale. Users pay a certain percentage of distribution commission and marketing expenses based on the number of subscriptions. We will establish a flexible profit-sharing mechanism and regularly adjust the profit-sharing ratio based on market dynamics and sales performance. At the same time, ensure good communication with partners and jointly develop market strategies to achieve long-term win-win results for both parties.

   C.   Advertising Revenue

   We will increase profitability by introducing advertisers and providing

healthcare and other related advertising services. The system attracts a large number of healthcare professionals and patient groups related to depression, creating a targeted and highly focused advertising market for related medical companies, pharmaceutical companies and health service providers. We will adopt a non-intrusive advertising strategy to ensure that the advertising content is highly relevant to user needs and interests while maintaining the user experience.

D. Research report income

We regularly publish industry reports and market research reports to reveal the trends and patterns of depression and mental health problems, and provide perspectives and experience for clinical medicine, psychology, and medicine. At the same time, we establish partnerships with academic institutions and non-profit organizations, share anonymized data, support their research in the field of mental health, obtain potential research funding and project cooperation opportunities, and achieve a win-win situation.

3. **Overall Design**

3.1 Product introduction

ZenSleep is a mobile app based on the Android platform that aims to help users improve their sleep quality. The main features of ZenSleep are comprehensiveness, personalization and community support.

3.1.1 Product positioning

- Target market: All users who need to improve their sleep, especially urban people who are troubled by sleep problems.
- Product mission: To provide comprehensive sleep solutions to improve the physical and mental health of users.

3.1.2 Overview of product functions

- Sleep music and sound
- Goodnight Community
- Nap timer
- Recording Note
- Personalization
- Sleep aid module
- Detailed sleep report

3.2 Features and innovations of the work

3.2.1 **An Effective Sleep Staging Framework**

This project uses the attention-based multi-channel EEG signal sleep staging method AMCSleepNet . This framework has three technical highlights: First, high accuracy and robustness: AMCSleepNet has an accuracy of over 96% and is highly robust to noise in biological signals; second, automatic labeling: automatic labeling of data through this system can greatly help analyze experimental results.

3.2.2 Accurate depression screening algorithm

This project uses a deep residual network (PC-DRN) based on a pyramid convolutional layer to achieve automatic classification of sleep stage images. The technical features of this framework are: constructing a pyramid convolutional layer for multi-scale feature extraction, and then performing feature fusion to achieve comprehensive feature extraction; connecting deep CNN in a residual manner can help overcome network degradation problems.

3.2.3 Scientific real-time brainwave music system

This project will use a real-time brainwave music system to regulate depression. Compared with traditional depression screening or treatment methods, this system can not only monitor and analyze the subject's brainwave data in real time, but also generate personalized music based on this data to alleviate depression symptoms. The system uses advanced eight- channel brain-computer equipment and wireless transmission technology to ensure the accuracy and real-time nature of data collection. Through complex mathematical models and formulas, the system can accurately map parameters such as brainwave amplitude, events, and energy to factors such as pitch, length, and intensity of music.

3.2.4 The value of interdisciplinary research

This project integrates knowledge and technologies from multiple fields such as computer science, artificial intelligence, medicine, and music. It introduces data science into the field of mental health and integrates music therapy into the auxiliary treatment of depression. Through interdisciplinary perspectives, the project provides a new direction for understanding the pathological mechanisms of depression and provides a comprehensive and innovative solution for the diagnosis and treatment of depression.

4. User Interface Design

4.1 User Interface

- XML/ ConstraintLayout : Used to design responsive user interfaces.
- Material Design: Follow the Material Design guidelines to provide a beautiful and consistent user interface.
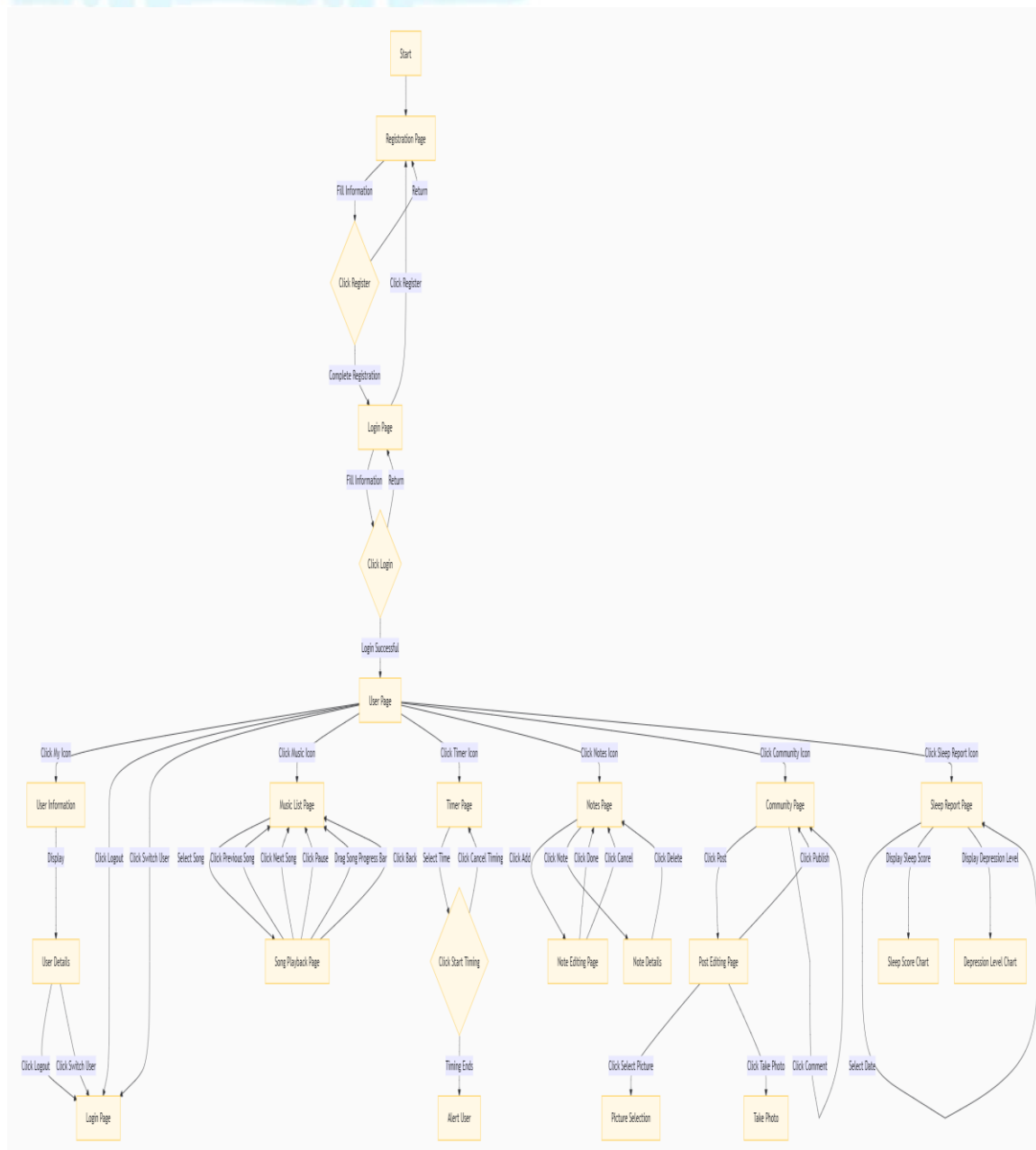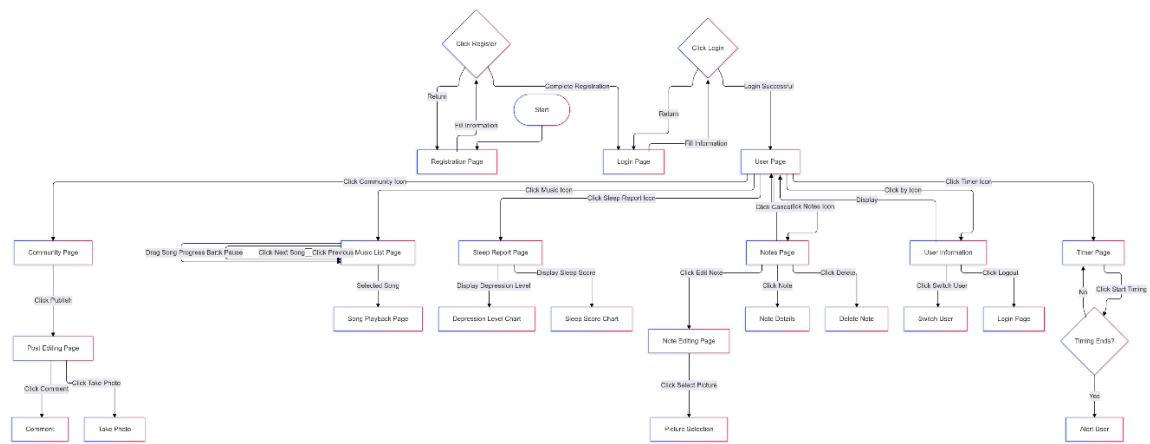
Below is the User Screen Flows :

Figure 1. User Screen Flows

4.2.1 Registration Page

- The user enters his name, email address and password on this page to register an account,.
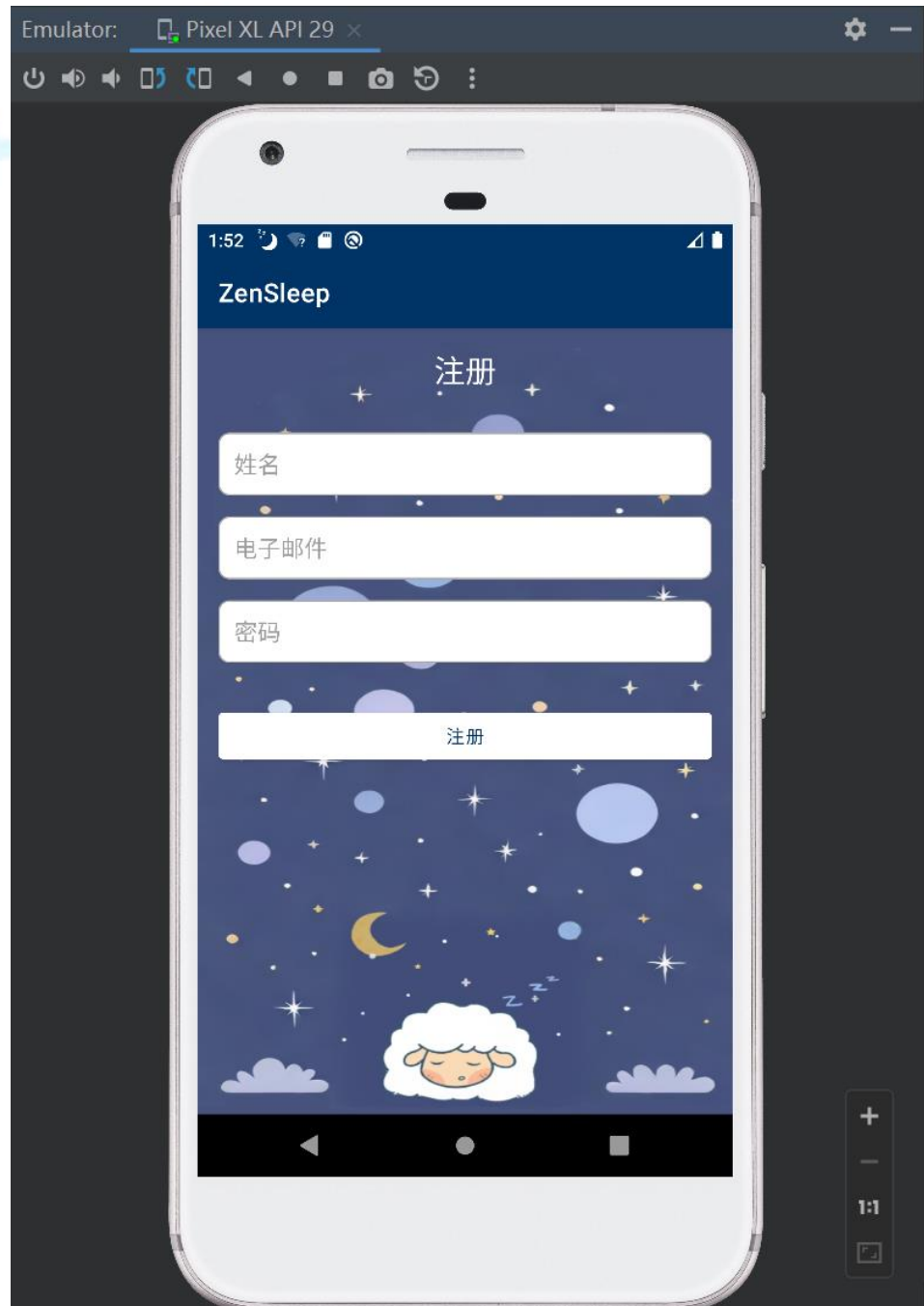- Clicks Register to complete the account registration, and then the page jumps to the login page.

Figure 2.   Registration page

4.2.2 Login Page

- Enter the username, email address and password of the registered

account on this page, click Login to enter the APP.

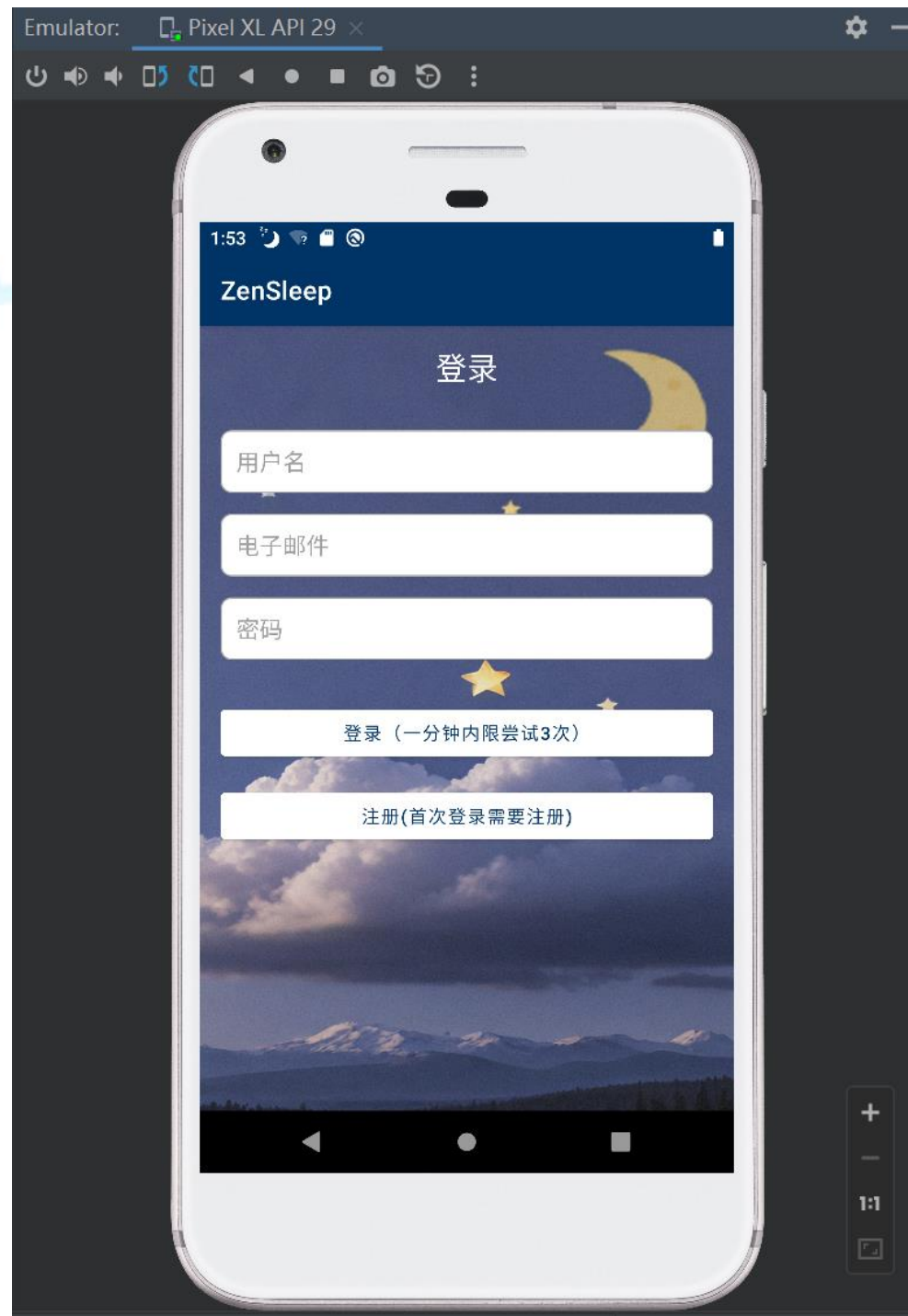- If you want to register an account, click Register to jump to the registration page.

Figure 3.   Login Page

4.2.3   User Page

- Click the My icon in the bottom navigation bar to enter the user page, which displays the logged-in user's avatar, registered email address, and user name. The following list also displays the user's use

of the APP information;
- Click "Logout" to log out of the account and return to the login page; click "Switch User" to enter the login page and the user can log in to the new account.

Figure 4.　User Page

4.2.4 Sleep aid module
- After logging into the APP, the first page displayed is the music list page, which shows all the sleep-aiding songs in the background.
- When users click on the song they want to listen to , they will jump to the listening page of the song;
- On the listening page, the song title and author name of the selected

song are displayed.
- Users can click on the previous song, next song or pause, or drag the song progress bar and click the page back to return to the song list page.
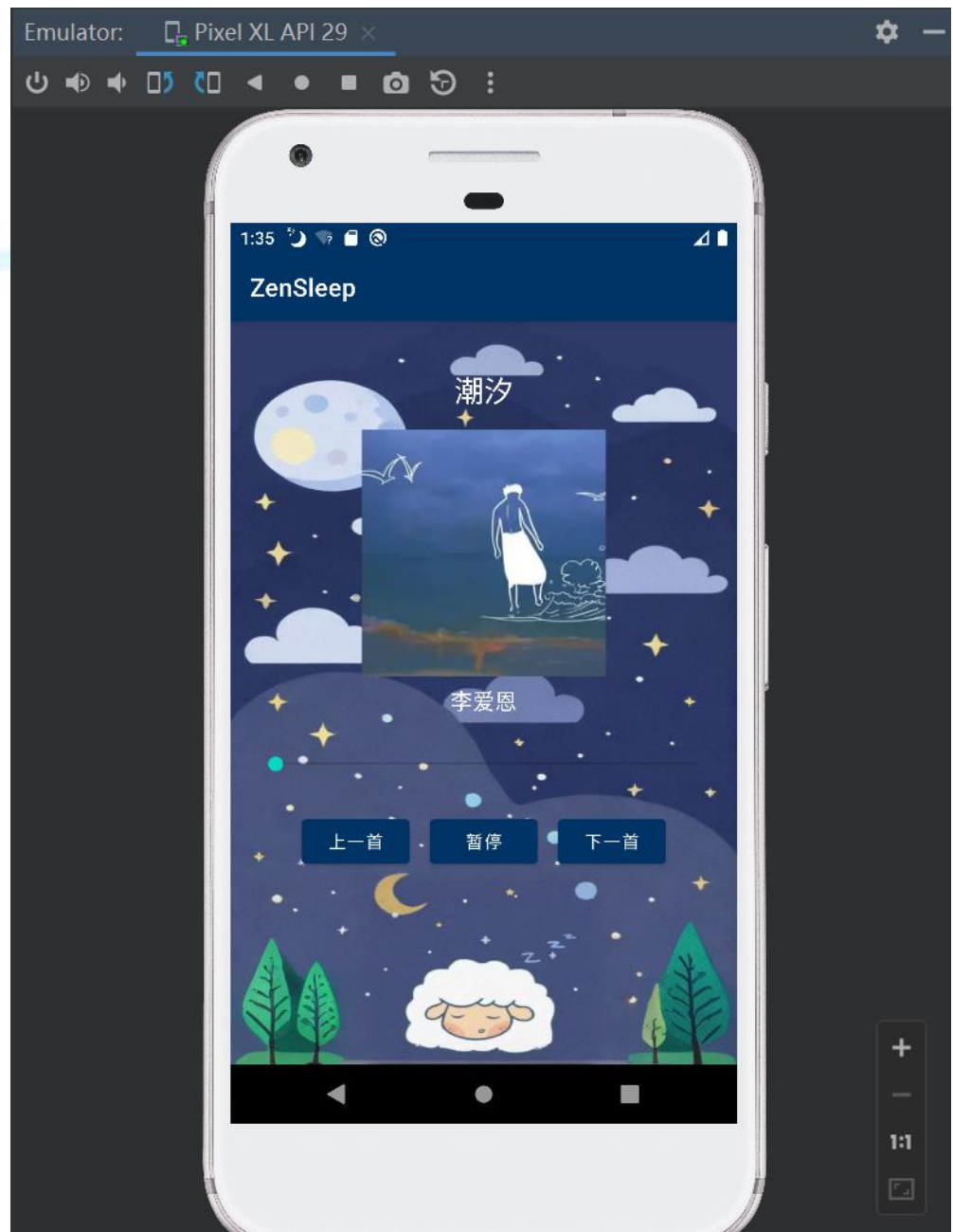

Figure 5.   Sleep aid page

4.2.5 Alarm clock module

- Click the timing icon in the bottom navigation bar to enter the nap timing page. Users can scroll the digital axis to select the time to be counted.
- After selection, there will be text at the bottom showing the corresponding ringing time. Users click "Start Timing" and the APP will

enter the countdown interface.
- •   At the same time, there will be a prompt to inform the user to start timing.
- • Click "Cancel Timing" to stop timing. After the countdown is over, the phone will ring and vibrate to remind the user that the countdown is over and it is time to end the nap.
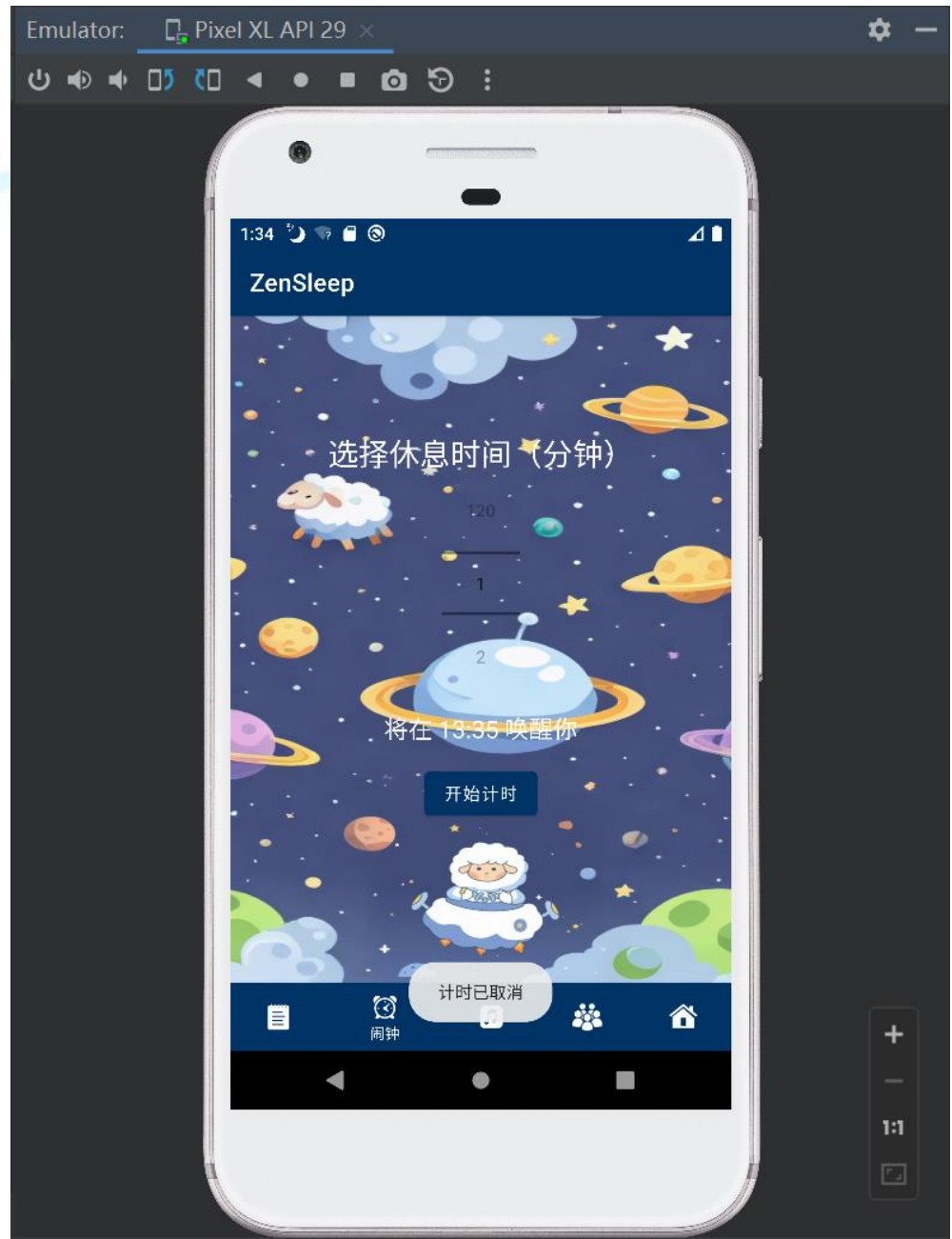

Figure 6.   Alarm Page

4.2.6   Recording Module

- • Click the note icon in the bottom navigation bar to enter the note page. The list on this page displays the user's note records. Each note shows the content of the note and the date and time when the note was edited. Click the note to

delete the record.

- Click "Add" below to enter the note editing page, where you can edit the content. Click "Done" to save the note. Click "Cancel" to exit the editing page and the note content will not be saved.
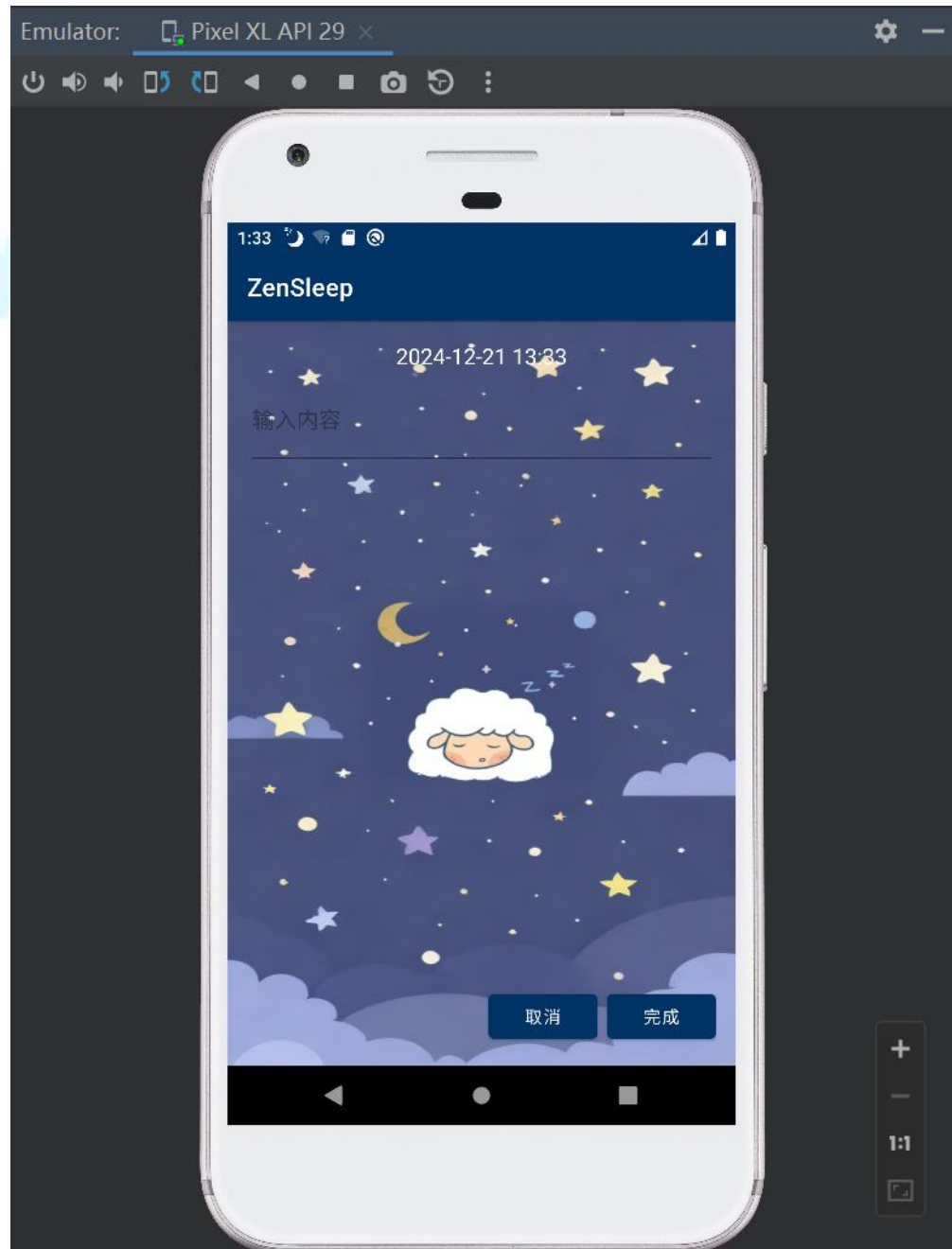

Figure 7. Notes Page

4.2.7 Community Module

- Click the community icon in the bottom navigation bar to enter the community page. The list on this page displays various shared information of users in the community.
- Each information bar displays the content of the information bar and the name of the user who edited the information bar. Users can click

the star icon to like it, or click the pencil icon to comment.
- Click the "+" in the lower right corner to enter the page for posting and editing information strips. You can edit the content on this page.
- You can click "Select Picture" to select photos from the phone memory, or click "Take Photo" to take photos in real time.
- Click "Publish" to publish the information strip and return to the community page.
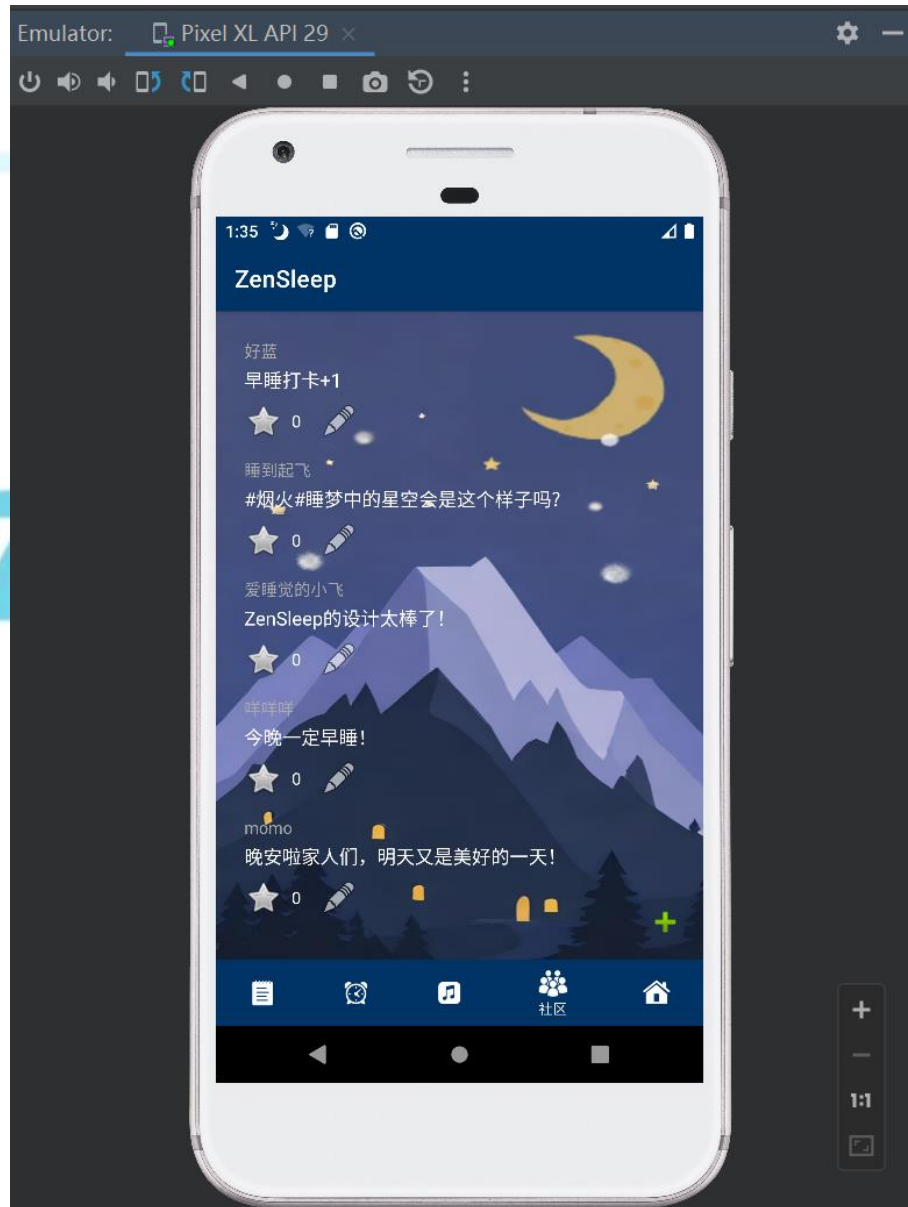

Figure 8. Community Pages

4.2.8 Detailed sleep report module
- A date selector is displayed at the top of the page, and the currently selected date is December 20, 2024. Users can select a different date to view sleep data by clicking the date selector.
- There is a circular chart in the middle of the page, which shows the user's sleep score, which is currently 76 points. The chart is divided into

three parts, with different colors representing different sleep stages: light sleep, snoring, and deep sleep. The size of each part represents the proportion of the sleep stage in the total sleep time.

- Below the sleep score graph, there is a pie chart showing the user's depression level. Most of the area in the chart is green, labeled "No Depression", and has a value of 1,048, which represents the depression index derived by the algorithm.

Figure 9.   Sleep Report Page

5. **Key Technologies**
    5.1 Core Technology
        5.1.1   Android development technology
            Android Studio is used as the development environment, and Kotlin or Java

language is used for programming. The application adopts a modular architecture to ensure the maintainability and extensibility of the code.

5.1.2 System components
- Activity: Used to manage the app's interface and user interaction.
- Service: runs in the background and supports music playback and timer functions.
- Broadcast Receiver: Used to receive system and in-app broadcasts, such as alarm alarms.
- Content Provider: manages data storage and sharing within applications, such as diary recording.

5.1.3 Sensor technology
- Light sensor: Adjust the brightness of the screen to protect the user's eyes.
- Microphone: Captures ambient noise and provides features such as white noise.

5.1.4 Data analysis and machine learning
- Sleep data analysis: provides personalized sleep recommendations by collecting users' sleep data.
- Machine learning algorithms: Continuously optimize recommended music and sounds based on users' usage habits and feedback.

5.1.5 Cloud Services and Databases
- Firebase: For user authentication, data storage and real-time database with support for community features and data synchronization.
- Cloud storage: Stores content uploaded by users, such as diaries, photos, etc.

5.2 System Implementation
5.2.1 Application architecture design
- Front-end interface layer: responsible for the interaction with users, including the UI design of each function module.
- Business logic layer: dealing with the core logic of the application, such as music playback control, timer operation, etc.
- Data layer: Manage data storage and reading locally and in the cloud.

5.2.2 Implementation of function module
A. Sleep music and sound
- Music player integration: Support loop play, random play and playlist management.
- Audio Resource Management: Store and manage local and online music and sound files.
- Personalize recommendations: Recommend suitable music based on the user's preferences and usage history.

B. Goodnight Community
- User registration and login: implemented using Firebase Authentication.
- Community interaction: Support post, comment, like and private message and other functions.
- Content moderation: Ensuring that community content is healthy and positive.

C. Nap timer
- Timer function: Support user-defined time duration, provide a variety of prompts.
- Background running: Even if the application is in the background, the timer can still work normally.
- Calendar integration: Nap schedules can be added to the user's calendar.

D. Recording Note
- Text editor: Support text, expression and picture insertion.
- Data encryption: to protect the user's privacy, diary content is only visible to the user himself.
- Data backup and recovery: Support local and cloud diary backup.

E. Detailed sleep report
- A circular chart in the middle of the page, which shows the user's sleep score.
- Below the sleep score graph, there is a pie chart showing the user's depression level.

5.3 Technical Challenges

5.3.1 Camera usage and call gallery

i. Call the gallery
- When the Select Image button is clicked, the Intent launches the gallery selector, allowing the user to select one or more images from the gallery.
- Use pickImagesLauncher to receive the results.

ii. Use a video camera to take pictures
- When the take a picture button is clicked, the Intent starts the system camera, captures the picture, and returns it.
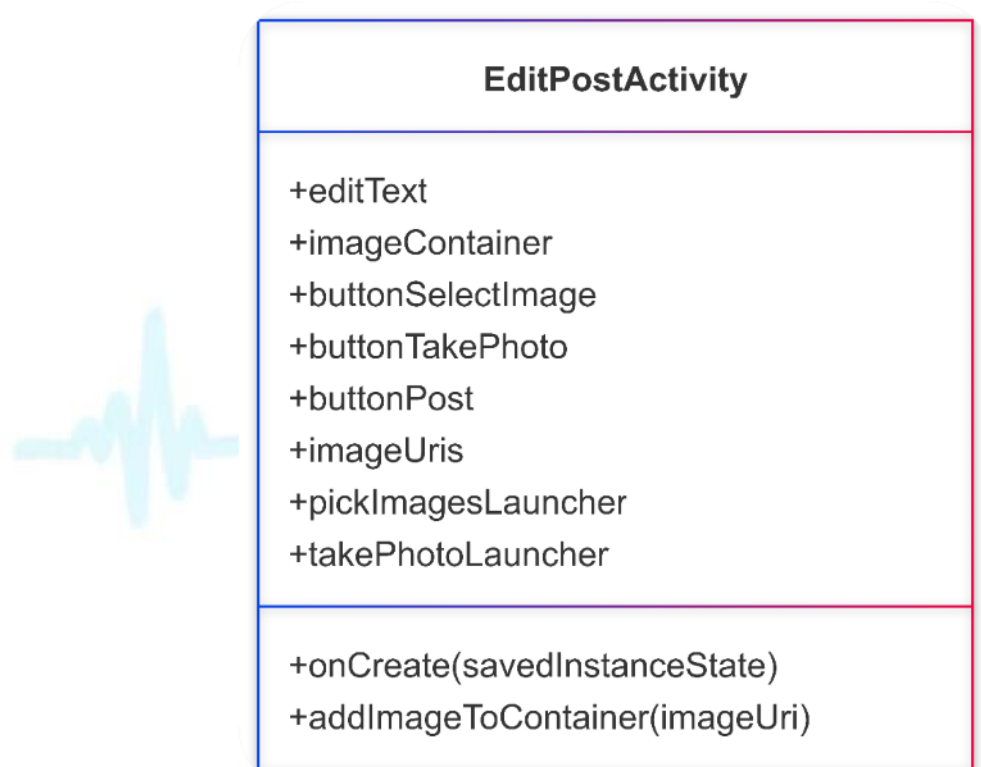- Use takePhotoLauncher to receive the photo result.
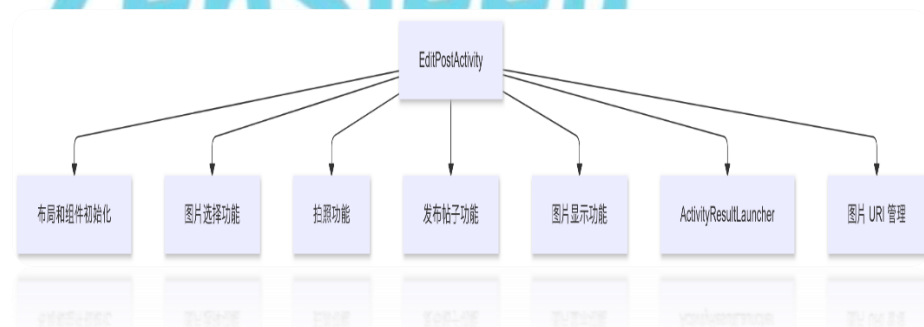
Figure 10. EditPostActivity1

Figure 11. EditPostActivity2

5.3.2 Realization of alarm clock vibration

The 'TimerBroadcastReceiver' class in the Android app written in Kotlin. This class inherits from 'BroadcastReceiver' and handles timer broadcasting.
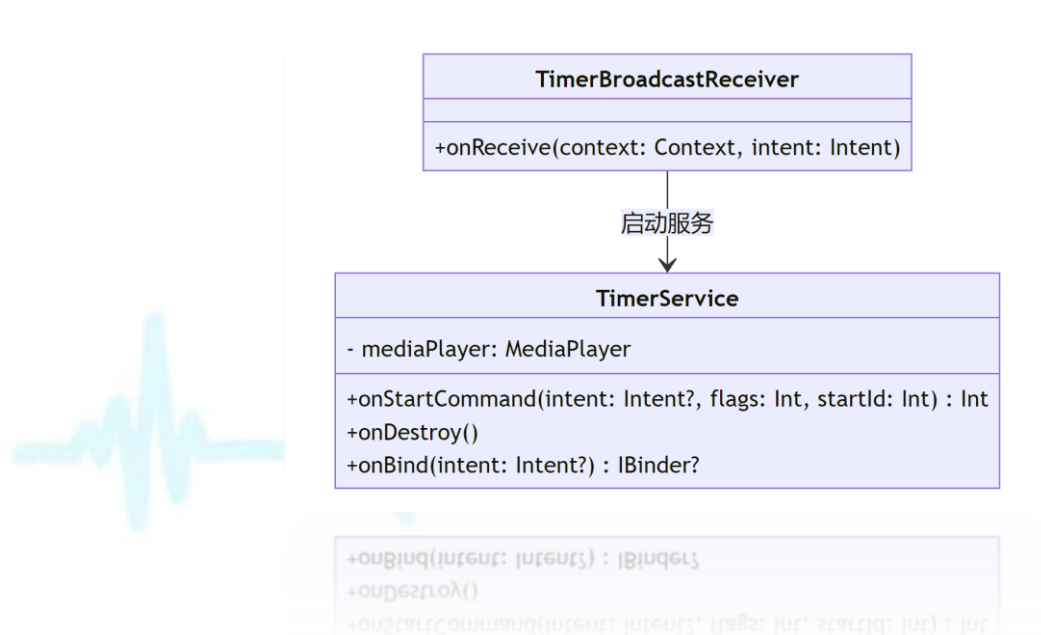
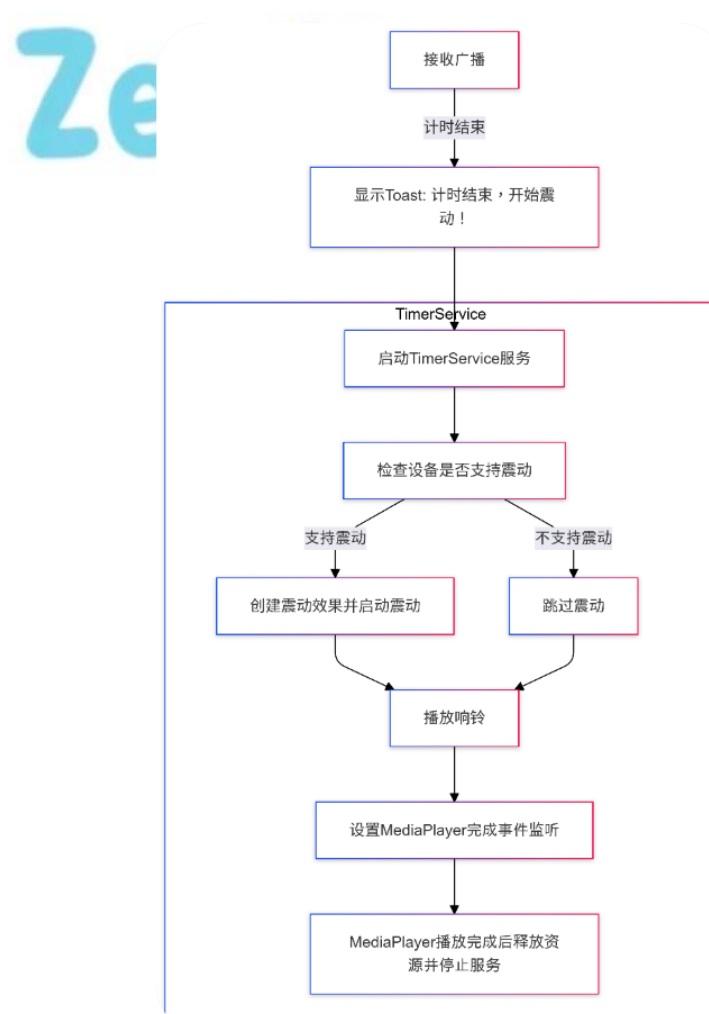**Figure 12.** **TimeBroadcastReceiver1**

Figure 13. **TimeBroadcastReceiver2**

5.3.3   Schedule delays and risk management
  i.   Delay in schedule
           Due to frequent requirement changes and technical problems, our
           project schedule was seriously affected and the project was delayed.

  ii.   Increased risk
           Schedule delays increase the risk of the project. We face multiple risks
           such as missed delivery, quality degradation, cost overruns, and need
           to take urgent measures to manage risk.

  iii.   Countermeasures
           In response to schedule delays and heightened risk, we have
           strengthened risk management. We have developed detailed risk
           response strategies and plans to ensure that the project proceeds as
           smoothly as possible.

6. Testing and User Experience Analysis
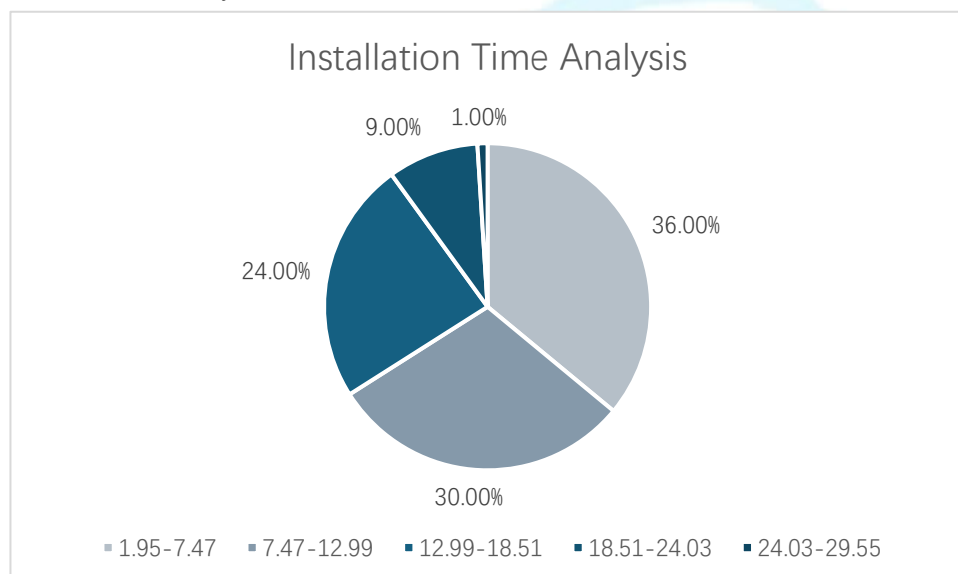6.1 Basic display of software testing and software completion
  A.   Test plan
  The test scheme we use is Baidu MTC mobile App test scheme, which includes the
  following two aspects of the test content.
  i.   Script compatibility testing
        This test covers mainstream models in the market, testing installation, startup,
        main functions and uninstallation; Customizable test scripts to cover required
        pages and core functions; Test reports contain use case details, screenshots,
        logs, performance data, and BUG details.

  Performance analysis
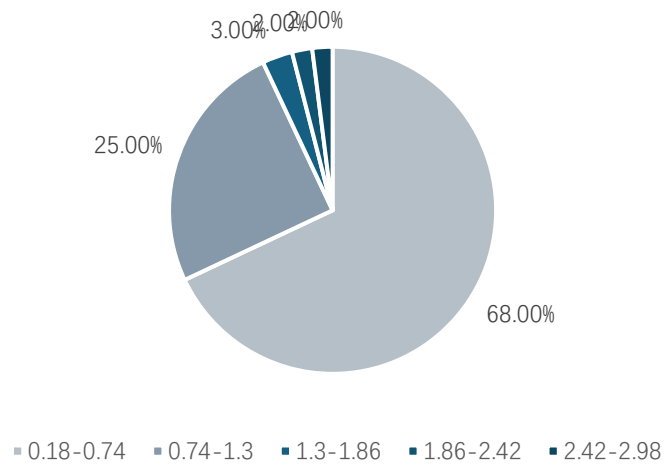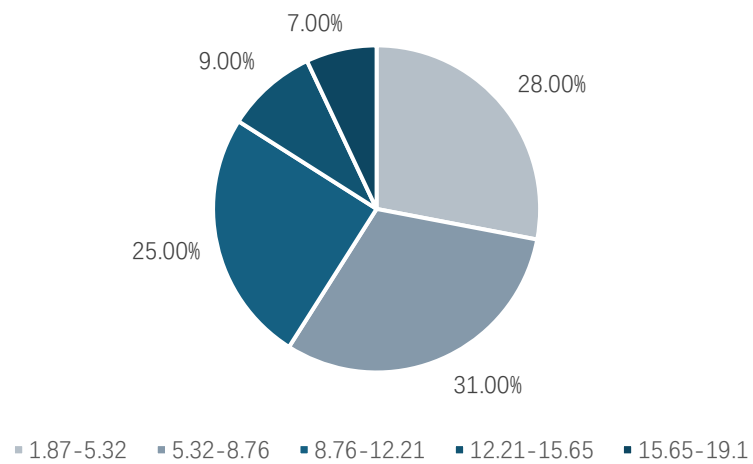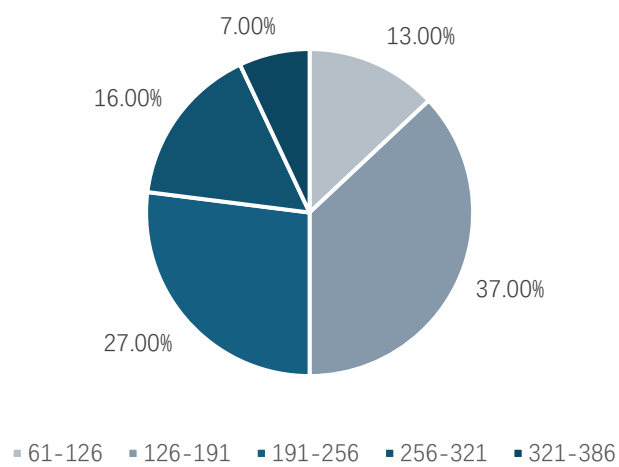
Installation Time Analysis

1.00%
9.00%
36.00%
24.00%
30.00%

■ 1.95-7.47   ■ 7.47-12.99   ■ 12.99-18.51   ■ 18.51-24.03   ■ 24.03-29.55

Start-up Time Analysis

3.00% 2.00% 2.00%
25.00%
68.00%

0.18-0.74 0.74-1.3 1.3-1.86 1.86-2.42 2.42-2.98

CPU Usage Analysis

7.00%
9.00%
28.00%
25.00%
31.00%

1.87-5.32 5.32-8.76 8.76-12.21 12.21-15.65 15.65-19.1

Memory Usage Analysis

7.00%
16.00%
13.00%
27.00%
37.00%

61-126 126-191 191-256 256-321 321-386

Traffic Consumption Analysis

2.00% 7.00%
14.00%
41.00%
36.00%

- 213-2901 - 2901-5588 - 5588-8275 - 8275-10962 - 10962-13649

Power Consumption Analysis

2.00% 2.00% 4.00%
30.00%
62.00%

- 1.59-3.99 - 3.99-6.4 - 6.4-8.8 - 8.8-11.21 - 11.21-13.61

GPU Usage Analysis

17.00%
19.00%
40.00%
11.00%
13.00%

- 2.27-7.54 - 7.54-12.81 - 12.81-18.08 - 18.08-23.35 - 23.35-28.62
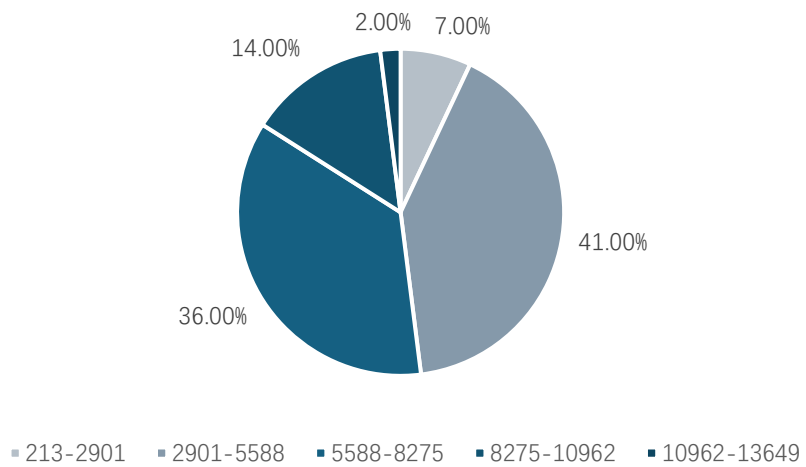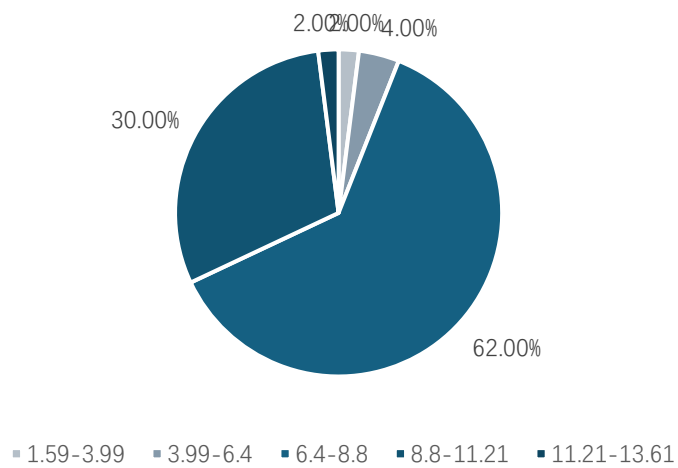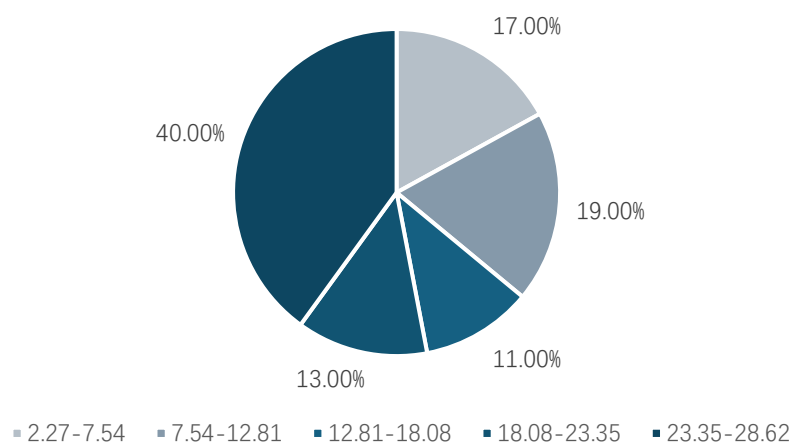
ii.   In-depth performance testing

Quasi-typical usage scenarios and states; Full access to startup time, power, traffic, CPU, etc.

Start-up Time

■ 启动耗时

CPU Usage

■ CPU占用

Memory Usage

Memory Usage (MB)

150

100

50

0

三星Galaxy56 Edge　三星Galaxy S7　三星GalaxyA8　华为Ascend P7　华为P9 标准版

■内存占用

Traffic Consumption

Traffic Consumption (KB)

6000

4000

2000

0

索尼L39h　华为Y639-CL00　华为GT-N7100　HTC Desire816　索尼LT26i

■流量耗用
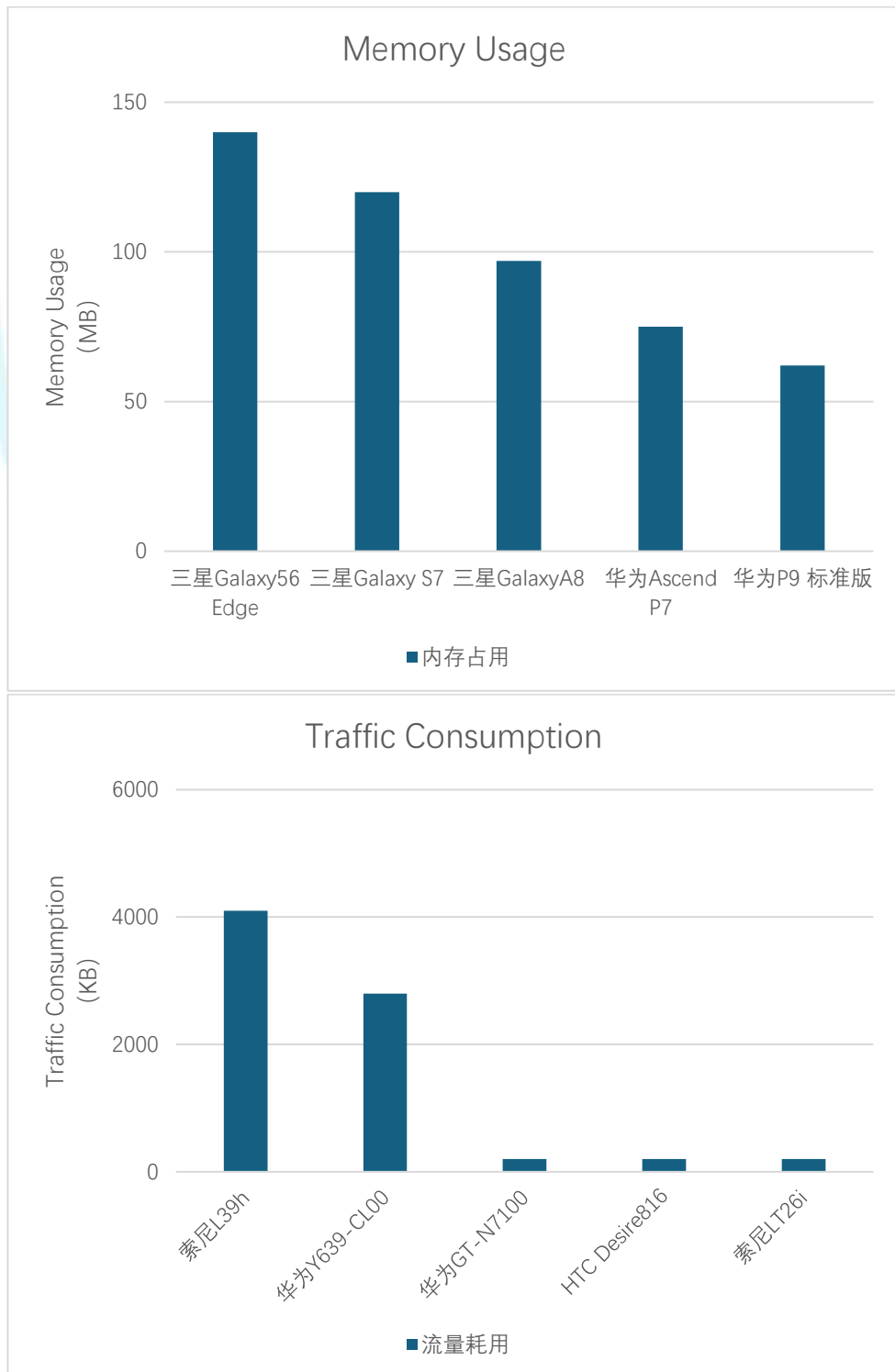
B.　Analysis of test results

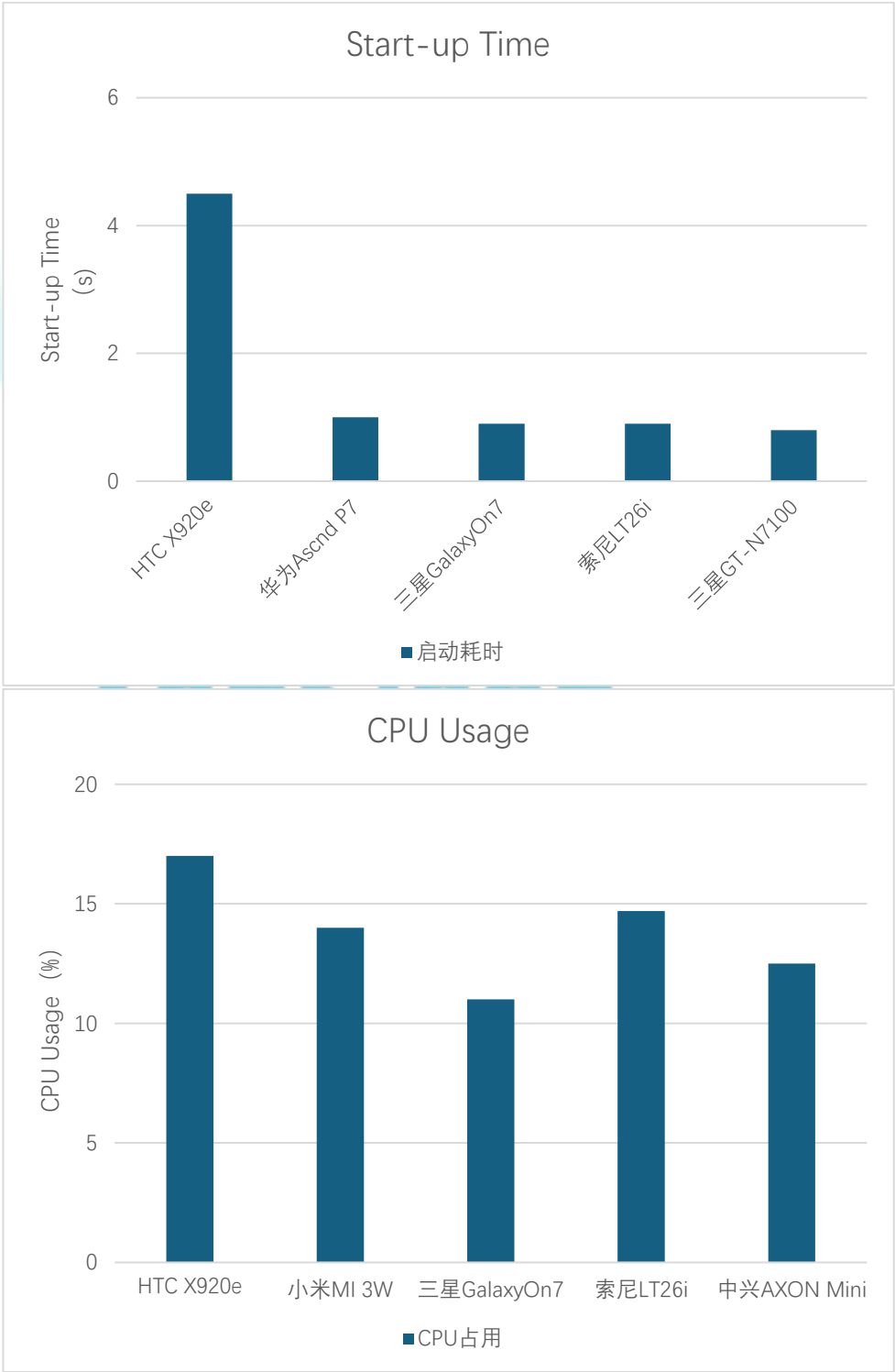We analyze the test results of the previous two aspects one by one.

i.　Script compatibility Analysis

The installation time is up to 29 seconds, probably because our APP is relatively large, and the resources that occupy the most storage should be the interactive interface and music. At the same time, you can see that the memory usage and power consumption are relatively large.

ii. In-depth performance analysis

From the conclusion overview, we can see that our App is still working well, but it still gets stuck. We think it is related to the network environment, if the network environment is too bad, it may appear stuttering or even stuck.

iii. Manual testing and analysis

The functions are diversified, and the page switching is smooth. Some pages are not compatible with all types of mobile phones. If a mobile phone with an incomplete screen is used, the defect area will be partially dark. There will be a slight lag in the use of the process, it is recommended to optimize and improve.

6.2 User Experience Analysis

A. User opinions, reviews, and developer analysis

Number	User	App Review	Suggestions for Improvement	Developer Analysis
1	Xiao Li	Pretty good.	Could add more music content.	The music content was only selected simply during development; more types of music will be added later.
2	॰	Beautiful interface	Some fonts could be changed.	Some fonts on certain pages are a bit jarring and will be adjusted.
3	Xiao Yu	Good	Sometimes it's a bit laggy, could be adjusted accordingly.	Related to the network of the test environment, will be adjusted later.
4	Tong	Nice interface, rich content	Add an option to adjust the sleep timer.	The sleep countdown was only designed simply, and will be adjusted

				subsequently.
5	Xu	The functions are comprehensive.	The layout of the pages needs further optimization.	Some page layouts are not appropriately eye-catching.
6	W	Pretty good	Could add a sleep check-in feature	This will be added in the future.
7	Yhm	Perfect	No suggestions	

7. **Conclusion**

    7.1   Summary of the project

    A.   Summary

    The ZenSleep project is a mobile application designed for the Android platform, aiming to address the prevalent issue of sleep disorders in modern society. With a significant portion of the global population, especially in China, experiencing sleep problems, ZenSleep seeks to fill a market gap by offering a comprehensive and personalized sleep aid solution that integrates technology with Eastern Zen philosophy.

    The application provides a multi-functional approach to improving sleep quality, including sleep music and sounds, a Goodnight Community for user interaction, a nap timer, and a diary function for personal reflection. ZenSleep's innovative features are deeply rooted in Zen principles, focusing on both the physical and mental well-being of users.

    Technologically, the app leverages Android development, sensor technology, and data analysis with machine learning to provide tailored sleep recommendations. Firebase is utilized for user authentication, data storage, and real-time database support, ensuring a robust and scalable backend.

    The marketing strategy for ZenSleep involves a multi-channel approach to rapidly increase brand awareness and capture a significant market share, with the goal of becoming a leading sleep aid app within three years.

    Overall, ZenSleep is poised to offer a unique and effective tool for users seeking to improve their sleep quality and enhance their quality of life, blending modern

technology with ancient wisdom.

B. Team division and cooperation effectiveness

Zhang Jiahui: Responsible for the explanation of the report, the main development of the APP, completed the page layout and function implementation of the APP, and sorted out the problems encountered in the APP development process and the solutions.
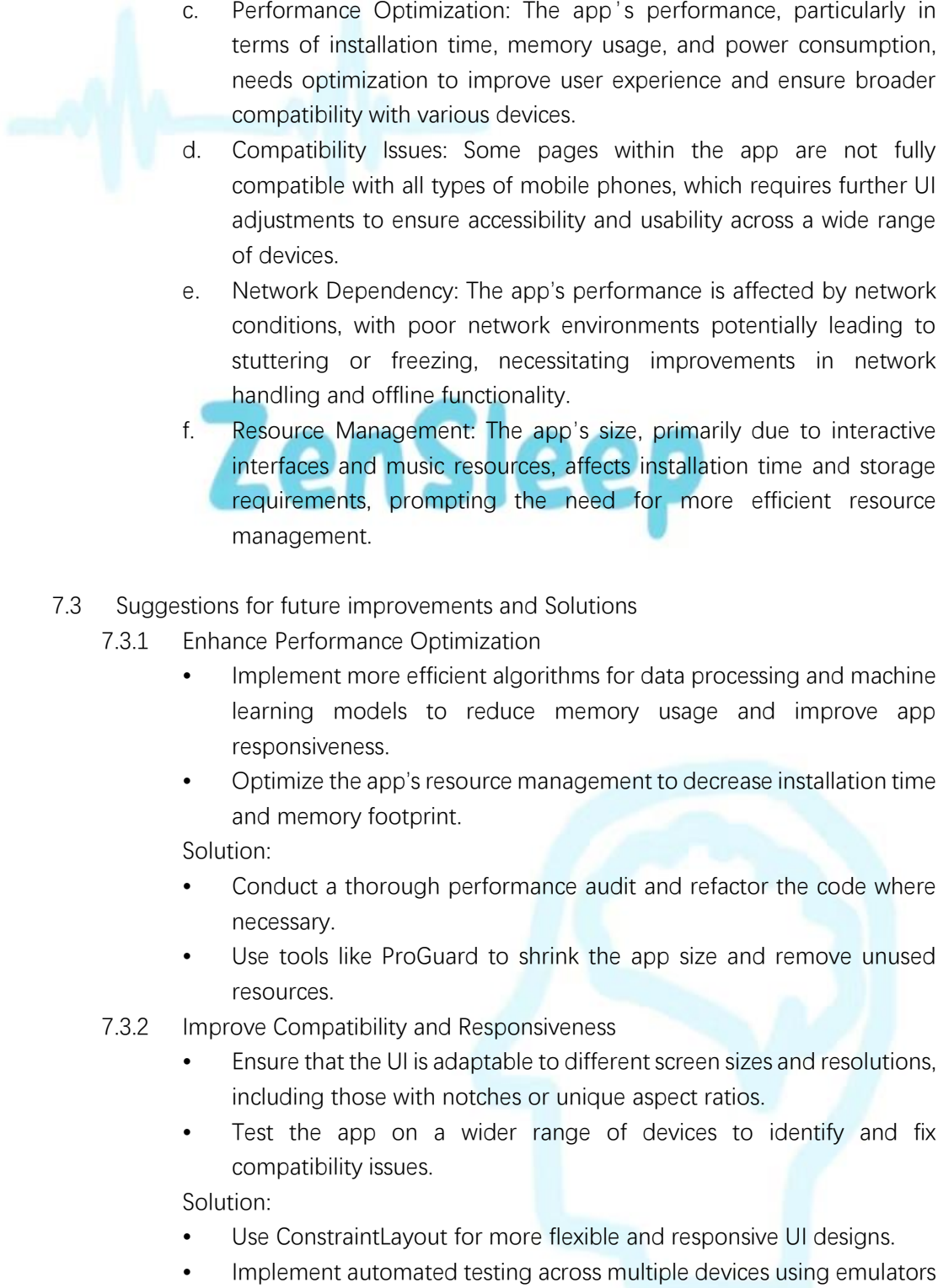
Wen Xiaoxue: Responsible for the production of PPT, the compatibility test and performance test of APP, and the analysis and arrangement of user experience. In the process of team cooperation, the division of labor was clear and the communication was smooth. The initial idea of the APP was basically realized, the development of ZenSleep was perfectly realized and the report was shared together.

7.2 Achievements and Challenges

7.2.1 Achievements

a. Development of an Effective Sleep Staging Framework: The project successfully implemented the AMCSleepNet framework, which has achieved over 96% accuracy in sleep staging and demonstrates high robustness against noise in biological signals, a significant milestone in sleep technology.

b. Accurate Depression Screening Algorithm: The PC-DRN deep residual network has been effectively used for automatic classification of sleep stage images, providing a comprehensive feature extraction method that contributes to the accurate screening of depression.

c. Scientific Real-time Brainwave Music System: The project has developed a pioneering system that regulates depression through real-time brainwave analysis and personalized music generation, offering a novel approach to mental health treatment.

d. Interdisciplinary Research Integration: By merging knowledge from computer science, AI, medicine, and music, the project has created a comprehensive and innovative solution for the diagnosis and treatment of depression, showcasing the value of interdisciplinary collaboration.

e. User Interface Design and Implementation: The project has successfully designed and implemented a user-friendly interface that follows Material Design guidelines, ensuring a consistent and aesthetically pleasing user experience across various modules.

f. Function Module Development: The project has successfully developed key function modules, including sleep aid, alarm clock, recording, community interaction, and detailed sleep report generation, providing a robust set of features for users.

g. Risk Management: Despite schedule delays, the project team has effectively managed risks by developing detailed risk response strategies and plans, ensuring the project's progress remains on track.

7.2.2 Challenges

a. Technical Complexity: Integrating advanced technologies like EEG signal analysis, deep learning, and real-time music generation presented significant technical challenges that the team had to overcome.

b. Schedule Delays: The project faced delays due to frequent requirement changes and technical problems, which increased the risk of missing delivery deadlines and required urgent measures to manage.

c. Performance Optimization: The app's performance, particularly in terms of installation time, memory usage, and power consumption, needs optimization to improve user experience and ensure broader compatibility with various devices.

d. Compatibility Issues: Some pages within the app are not fully compatible with all types of mobile phones, which requires further UI adjustments to ensure accessibility and usability across a wide range of devices.

e. Network Dependency: The app's performance is affected by network conditions, with poor network environments potentially leading to stuttering or freezing, necessitating improvements in network handling and offline functionality.

f. Resource Management: The app's size, primarily due to interactive interfaces and music resources, affects installation time and storage requirements, prompting the need for more efficient resource management.

7.3   Suggestions for future improvements and Solutions

7.3.1   Enhance Performance Optimization

- Implement more efficient algorithms for data processing and machine learning models to reduce memory usage and improve app responsiveness.
- Optimize the app's resource management to decrease installation time and memory footprint.

Solution:

- Conduct a thorough performance audit and refactor the code where necessary.
- Use tools like ProGuard to shrink the app size and remove unused resources.

7.3.2   Improve Compatibility and Responsiveness

- Ensure that the UI is adaptable to different screen sizes and resolutions, including those with notches or unique aspect ratios.
- Test the app on a wider range of devices to identify and fix compatibility issues.

Solution:

- Use ConstraintLayout for more flexible and responsive UI designs.
- Implement automated testing across multiple devices using emulators

and real devices.

7.3.3 Reduce Network Dependency
- Develop offline capabilities for key features to ensure the app remains functional without an internet connection.
- Implement caching mechanisms for frequently accessed data.

Solution:
- Design the app architecture to support local data storage and retrieval.
- Use Firebase's offline capabilities to sync data when the network is available.

7.3.4 Strengthen User Privacy and Data Security
- Implement robust security measures to protect user data, especially in the context of sensitive health information.
- Provide clear privacy policies and user consent mechanisms.

Solution:
- Use encryption for storing and transmitting sensitive data.
- Regularly update the app to address any security vulnerabilities.

7.3.5 Expand and Personalize the Music Library
- Introduce a more diverse range of music and sounds to cater to different user preferences.
- Implement a recommendation system that learns from user interactions to suggest personalized content.

Solution:
- Collaborate with music therapists to curate a specialized music library.
- Use machine learning algorithms to analyze user preferences and improve recommendations.

7.3.6 Enhance Community Features
- Add more interactive elements to the community module, such as forums, challenges, or group activities.
- Implement moderation tools to maintain a healthy and positive community environment.

Solution:
- Integrate community feedback mechanisms to gather user suggestions for new features.
- Develop a set of community guidelines and automated content filtering systems.

7.3.7 Continuous Integration and Deployment
- Establish a CI/CD pipeline to streamline the development, testing, and deployment process.
- Implement automated testing to catch bugs and issues early in the development cycle.

Solution:
- Use services like Jenkins, GitLab CI/CD, or GitHub Actions to automate the build and deployment process.
- Write comprehensive unit and integration tests to cover critical app

functionalities.