Trackify: Mobile Network Monitoring and Feedback Application

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Trackify: A Mobile-Based Network Monitoring and Feedback Application

A Dissertation Submitted to the Faculty of Engineering and Technology in Partial Fulfillment of the Requirements for the Award of a Bachelor's Degree in Engineering

University of Buea

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Certification of Originality

This is to certify that the project titled **"Trackify: A Mobile-Based Network Monitoring and Feedback Application"** was carried out by the undersigned student. This work is submitted in partial fulfillment of the requirements for the award of a Bachelor's Degree in Engineering from the University of Buea.

The project represents my original work, and to the best of my knowledge, it has not been submitted previously to any other university or institution for any degree.

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Supervisor

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[Head of Department's Name]

Head of Department

Dedication

This project is dedicated to:

- My beloved parents, for their unwavering love, endless encouragement, and financial support throughout my academic journey.
- My supervisor, Professor [Supervisor's Last Name], for his invaluable guidance, patience, and expert advice, which were instrumental in shaping this work.
- My friends and colleagues, whose collaboration, motivation, and shared experiences made this challenging endeavor a rewarding one.

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Furthermore, I wish to acknowledge the support of my friends and family. Their continuous moral support, understanding, and belief in my abilities provided the motivation needed to overcome obstacles. Lastly, I extend my thanks to anyone who directly or indirectly contributed to this project's fruition.

Abstract

The proliferation of mobile devices has underscored the critical importance of robust and reliable mobile network services. However, users frequently encounter performance issues such as dropped calls, slow data speeds, and inconsistent coverage, particularly in regions facing infrastructure limitations. Existing methods for assessing mobile network quality often rely on technical benchmarks that may not fully capture the end-user experience. This dissertation presents **Trackify: A Mobile-Based Network Monitoring and Feedback Application**, a novel solution designed to address this gap by integrating real-time network performance data with direct user-reported feedback. The project aims to provide mobile network operators and stakeholders with a comprehensive, user-centric view of network quality.

Trackify employs a user-centered design methodology, prioritizing ease of use and intuitive interaction for the end-user. The application is developed using **React Native**, enabling cross-platform compatibility for both Android and iOS devices. For the backend infrastructure, a **MongoDB** NoSQL database is utilized for its flexibility and scalability in handling diverse data types, including user profiles, network metrics, and qualitative feedback. The system architecture facilitates the collection of key network parameters such as signal strength (RSSI), network type (e.g., 4G, 5G), and latency, alongside user-submitted reports detailing network issues experienced in specific locations.

The implementation involved developing a user-friendly mobile interface for data submission and a backend system to manage and process this information. Results from pilot testing demonstrate Trackify's capability to gather valuable data, correlating technical metrics with user-reported experiences. This integration provides actionable

insights for identifying network bottlenecks and areas requiring improvement. Trackify's primary contribution lies in its unified approach to network monitoring, merging objective performance data with subjective user sentiment to enhance the overall quality of service (QoS) and quality of experience (QoE) for mobile users.

Keywords: Trackify, Network Monitoring, Feedback App, Mobile Networks, Quality of Experience (QoE), React Native, MongoDB

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List of Tables

This section will provide a comprehensive list of all tables included within this dissertation. Each entry will detail the table's title and the corresponding page number where it can be found. This facilitates easy navigation and reference to the visual data representations supporting the project's findings.

List of Figures

The following figures have been incorporated into this dissertation to visually represent various aspects of the Trackify project, including system architecture, user interface designs, data flow diagrams, and results visualizations. Each figure is listed with its title and the page number on which it appears, aiding in the navigation and understanding of the presented information.

List of Abbreviations

This section provides an alphabetical compilation of all abbreviations used throughout this dissertation. These abbreviations are essential for understanding the technical terminology and concepts discussed in relation to the Trackify Mobile Network Monitoring Project.

- API: Application Programming Interface
- DB: Database
- ER: Entity-Relationship
- iOS: Apple operating system for mobile devices
- IP: Internet Protocol
- KPI: Key Performance Indicator
- NoSQL: Not Only SQL
- OS: Operating System
- QoS: Quality of Service
- QoE: Quality of Experience

- UI: User Interface
- UX: User Experience

CHAPTER ONE: GENERAL INTRODUCTION

1.1. Background and Context of the Study

The pervasive adoption of mobile technology has fundamentally reshaped how individuals communicate, access information, and conduct business. Mobile networks, the backbone of this connectivity, are expected to provide seamless and high-quality service. However, the reality for many users, particularly in developing regions or areas with evolving infrastructure, often falls short of this expectation. Users frequently encounter debilitating issues such as dropped calls, inconsistent data speeds, poor signal strength, and limited network coverage. These problems significantly degrade the user's experience and can have tangible economic and social consequences.

Traditionally, mobile network performance has been assessed through technical benchmarks conducted by network operators or third-party testing companies. These methods, while providing valuable objective data, often fail to capture the nuanced, subjective experience of the end-user. Factors like the perceived speed of data transfer, the reliability of voice calls in specific locations, and the overall satisfaction with the network service are best understood through direct user feedback. The disconnect between technical measurements and user-perceived quality of experience (QoE) presents a critical challenge for network providers aiming to optimize their services and enhance customer satisfaction.

Furthermore, in many contexts, particularly those with rapidly expanding mobile user bases and infrastructure development, there is a pronounced need for granular, real-time data that reflects the actual conditions experienced by users on the ground. This data can inform targeted infrastructure upgrades, network optimization strategies, and prompt responses to emerging issues. Without a systematic mechanism to collect and analyze this user-centric information, network operators are often working with incomplete or potentially skewed perspectives of their network's performance. This project, **Trackify: A Mobile-Based Network Monitoring and Feedback Application**, seeks to bridge this gap by developing a mobile application that empowers users to report their network experiences while simultaneously collecting relevant technical data.

1.2. Problem Statement

Despite the critical role of mobile networks in modern society, users frequently experience unreliable service characterized by poor signal strength, slow data speeds, dropped calls, and intermittent connectivity. This unreliability is often more pronounced in areas undergoing infrastructure development or those with geographical challenges, leading to a significant degradation in the **Quality of Experience (QoE)** for mobile subscribers. A key challenge in addressing these issues is the lack of a structured, user-friendly mechanism for collecting both qualitative user feedback and objective network performance data simultaneously from a broad user base.

Existing network monitoring solutions typically rely on passive probes or technical measurements performed by operators, which may not accurately reflect the end-user's perception of service quality. While some applications allow for bug reporting, they often lack the integration with real-time network metrics that would provide context to the reported issues. Consequently, network providers struggle to pinpoint specific problem areas, understand the root causes of user dissatisfaction, and prioritize infrastructure improvements effectively. There is a clear need for a tool that can:

- Enable end-users to easily report network issues they encounter.
- Simultaneously capture relevant, real-time network performance metrics (e.g., signal strength, network type, latency) at the time of the report.
- Aggregate and analyze this combined data to identify patterns, correlate user feedback with technical performance, and pinpoint network degradation zones.
- Provide actionable insights to mobile network operators for service improvement and infrastructure planning.

Without such a system, efforts to improve mobile network quality remain largely reactive and lack the direct insights that could be gained from the collective experience of the user base.

1.3. Objectives of the Study

This research aims to develop and evaluate a mobile application that enhances the understanding and improvement of mobile network performance by integrating user feedback with real-time technical data. The objectives of this study are twofold:

1.3.1. General Objective

To design, develop, and implement a mobile-based application, **Trackify**, that facilitates the collection of user-reported network issues and real-time network performance metrics, thereby providing actionable insights for improving the Quality of Experience (QoE) for mobile network users.

1.3.2. Specific Objectives

The general objective will be achieved through the following specific objectives:

- To investigate and understand the current challenges faced by mobile users regarding network quality and identify key performance indicators (KPIs) relevant to user experience.
- To design a user-centric mobile application interface that allows users to easily report network problems and provide contextual information.
- To develop a backend system capable of receiving, storing, and processing both user feedback and real-time network performance data (e.g., signal strength, network type, latency).
- To implement mechanisms within the mobile application to automatically capture relevant network metrics in the background or upon user action.

- To develop an administrative interface or dashboard for visualizing and analyzing the aggregated data, identifying trends, and correlating user-reported issues with network performance.
- To evaluate the effectiveness of the Trackify application in gathering meaningful data and its potential contribution to improving mobile network quality through preliminary testing and analysis.

1.4. Summary of Methodology

This project will adopt a blended approach, combining user-centered design principles with agile development methodologies to ensure the resulting application is both functional and user-friendly. The process will involve several key stages:

- **Requirements Gathering:** Through literature review and potentially user surveys or interviews (within the scope of a final year project), key user pain points and essential network metrics will be identified.
- **System Design:** A comprehensive system architecture will be designed, encompassing the mobile application (frontend), a robust backend server, and a database. The user interface (UI) and user experience (UX) will be meticulously planned using tools like Figma. The database schema, specifically for MongoDB, will be conceptualized to efficiently store user profiles, network data, and feedback entries.
- **Technology Stack Selection:** The project will leverage modern and widely adopted technologies. **React Native** will be used for the frontend development to ensure cross-platform compatibility (Android and iOS). A **Node.js** environment will likely be employed for the backend API development, facilitating communication between the frontend and the database. **MongoDB**, a NoSQL database, will be chosen for its flexibility in handling unstructured and semi-structured data, which is typical for user-generated content and varied network logs.
- **Development:** The application will be built iteratively, following agile principles. This involves developing core functionalities such as user authentication, feedback submission, and real-time metric capture in the mobile app, alongside the corresponding backend APIs and database operations. An admin dashboard will also be developed for data visualization.
- **Testing and Evaluation:** Rigorous testing will be conducted, including functional testing to ensure all features work as intended, usability testing to assess the user-friendliness of the interface, and performance testing to gauge the application's efficiency in data collection and transmission. Pilot testing with a small group of users will be performed to gather initial feedback and validate the system's effectiveness.

The methodology prioritizes creating a practical and scalable solution that directly addresses the identified problem of understanding and improving mobile network QoE.

1.5. Research Questions

This study seeks to answer the following research questions:

1. How can a mobile application effectively integrate real-time network performance metrics (e.g., signal strength, latency) with user-reported network issues to provide a comprehensive view of mobile network quality?
2. What are the key user-centric requirements for a mobile application designed to monitor and report on mobile network performance, particularly in areas with potential infrastructure challenges?
3. How can technologies like React Native and MongoDB be utilized to build a scalable and efficient mobile network monitoring and feedback system?
4. What are the potential improvements in Quality of Experience (QoE) that can be achieved by network providers utilizing the data and insights generated by the Trackify application?
5. What are the challenges and limitations associated with developing and deploying a user-feedback-driven network monitoring application?

1.6. Significance of the Study

The significance of the **Trackify** project lies in its potential to bridge the gap between the technical performance of mobile networks and the actual experience of their users. By providing a platform for direct, contextualized user feedback coupled with real-time network data, this study offers substantial benefits to several stakeholders:

- **For Mobile Network Users:** Trackify empowers users by giving them a voice to report issues they encounter, contributing directly to the improvement of the services they rely on. This can lead to a better overall **Quality of Experience (QoE)**, characterized by more reliable connectivity and faster data speeds.
- **For Mobile Network Operators (MNOs):** The application provides MNOs with invaluable, granular data from the end-user perspective. This data can complement traditional network monitoring tools, enabling them to identify specific areas of poor performance, understand the impact of network issues on user satisfaction, and make more informed decisions regarding network upgrades and optimizations. This targeted approach can lead to more efficient resource allocation and improved customer retention.
- **For Researchers and Academics:** This project contributes to the body of knowledge in mobile network performance monitoring, user-centric system design, and the application of modern mobile development technologies. It serves as a case study for integrating qualitative user feedback with quantitative network metrics, offering insights into methods for improving digital infrastructure.
- **For Device Manufacturers and App Developers:** The findings and methodologies employed can inform the development of future mobile applications and devices that are more aware of and responsive to network conditions, potentially leading to better app performance and user satisfaction across various services.

In essence, Trackify aims to foster a more collaborative approach to mobile network quality assurance, where user insights are actively leveraged to drive tangible improvements in service delivery.

1.7. Scope of the Study

The scope of this project is defined to ensure feasibility within the timeframe and resources typically allocated for a final year undergraduate engineering project. The Trackify application will focus on:

- **Target Users:** The application is primarily intended for individual mobile phone users who experience issues with their cellular network service.
- **Geographical Focus:** While the application is designed to be globally deployable, initial testing and data collection will likely be concentrated among mobile users within specific geographical areas or campuses where the development team has access to potential testers and can observe network conditions.
- **Network Types:** The application will focus on monitoring and collecting feedback related to cellular network services, including but not limited to 2G, 3G, 4G/LTE, and nascent 5G networks, as supported by the user's device and network provider.
- **Data Collected:** The application will collect user-reported issues (e.g., dropped calls, slow internet, no service) along with associated contextual information (e.g., location, time, description). It will also automatically capture technical network parameters available through the mobile operating system's APIs, such as Received Signal Strength Indicator (RSSI), network operator, network type (e.g., LTE, UMTS), and potentially latency measurements.
- **Platform:** The development will prioritize the Android operating system due to its widespread adoption and the ease of access to device hardware information. Cross-platform development using React Native will aim for compatibility with iOS, though specific testing and optimization may be more intensive on Android.

The project will deliver a functional prototype of the Trackify application, including the mobile client and a basic administrative interface for data viewing.

1.8. Delimitations

To maintain focus and ensure the project's completion within the defined constraints, certain aspects will be deliberately excluded or limited:

- **Core Network Infrastructure Analysis:** This project will not involve direct analysis or modification of the core network infrastructure of mobile network operators (e.g., base stations, cell towers, core network elements). The focus is on the user-facing experience and data accessible from the mobile device.
- **In-depth Forensic Network Analysis:** While the application collects network metrics, it is not intended as a sophisticated network analysis tool for deep packet inspection or detailed protocol-level diagnostics. The metrics collected are limited to those readily available via standard mobile OS APIs.

- **Provider-Specific API Integration:** The project will not integrate directly with proprietary Application Programming Interfaces (APIs) provided by mobile network operators, as these are typically restricted and require formal agreements.
- **Advanced Machine Learning for Prediction:** While the collected data could be used for predictive modeling, this project will focus primarily on data collection, aggregation, and basic trend visualization. Advanced predictive analytics are beyond the scope of this initial development phase.
- **Real-time Location Tracking (Continuous):** Continuous background location tracking will be avoided to conserve battery life and respect user privacy. Location data will primarily be captured at the time of a reported event or when the user explicitly initiates a monitoring session.
- **Financial Transactions or Billing:** The application will not handle any financial transactions or provide billing-related information.
- **iOS Platform Deep Optimization:** While React Native enables iOS compatibility, the primary focus for development and testing will be on the Android platform. Extensive, platform-specific optimizations for iOS may not be fully implemented.

These delimitations allow the project to concentrate on its core objective: creating a functional and valuable tool for user-driven mobile network monitoring and feedback.

1.9. Definitions of Key Terms

To ensure clarity and a common understanding of the concepts discussed throughout this dissertation, the following key terms are defined:

- **Mobile Network:** A telecommunications network in which a mobile device can communicate with other devices through radio waves and a network infrastructure.
- **Quality of Service (QoS):** Refers to the measurable performance parameters of a network, such as bandwidth, latency, jitter, and packet loss. It is a technical measure of network performance.
- **Quality of Experience (QoE):** Refers to the overall user satisfaction with a service, influenced by factors beyond technical QoS, including usability, reliability, and perceived performance. It is a subjective measure.
- **Trackify:** The name of the mobile application developed in this project, designed for monitoring network performance and collecting user feedback.
- **React Native:** An open-source UI software framework created by Meta Platforms, Inc. It is used to develop applications for Android, iOS, Web, and UWP by enabling developers to use React with native platform capabilities.
- **MongoDB:** A popular open-source NoSQL document-oriented database. It stores data in flexible, JSON-like documents, making it suitable for handling diverse data types and evolving schemas.
- **RSSI (Received Signal Strength Indicator):** A measurement of the received signal power level by a wireless device. Higher RSSI values generally indicate a stronger signal.

- **Latency:** The time delay in data transfer between the user's device and a network server. Lower latency is generally better for responsive applications.
- **User-Centered Design (UCD):** A design philosophy and process that places the user at the center of every design decision, focusing on understanding user needs and creating interfaces that are intuitive and efficient.
- **Agile Development:** An iterative approach to project management and software development that helps teams deliver value to their customers faster and with fewer headaches.
- **API (Application Programming Interface):** A set of rules and protocols that allows different software applications to communicate with each other.
- **NoSQL Database:** Databases that do not follow the traditional relational database model (SQL) and are designed for flexibility and scalability, often storing data in formats other than tables.

1.10. Organization of the Dissertation

This dissertation is structured into five chapters, each addressing a distinct phase of the Trackify project, from conceptualization to conclusion:

- **Chapter One: General Introduction** provides the foundational context for the project. It outlines the background of mobile network quality challenges, states the problem addressed, defines the general and specific objectives, summarizes the adopted methodology, poses key research questions, highlights the significance of the study, and defines the scope and limitations of the project.
- **Chapter Two: Literature Review** delves into existing research and technologies relevant to mobile network monitoring, quality assessment, user feedback systems, and mobile application development. It critically analyzes previous work, identifies gaps in current solutions, and positions Trackify within the broader landscape of network performance management.
- **Chapter Three: Analysis and Design** details the systematic process of gathering user requirements and translating them into a robust system design. This chapter covers the chosen methodology, system architecture, user interface mockups, database schema design (specifically for MongoDB), and the rationale behind technology choices.
- **Chapter Four: Implementation and Results** describes the practical execution of the system design. It elaborates on the development tools and technologies used, outlines the implementation stages, presents the application's features with relevant screenshots, details the backend and database setup, and discusses the results of functional testing, performance evaluation, and user feedback.
- **Chapter Five: Conclusion and Further Works** summarizes the project's achievements, reiterates its contributions to addressing the problem statement, discusses challenges encountered during development, and proposes recommendations for future enhancements and research directions.

Concluding the main body of the dissertation are the **References** section, which lists all cited sources, and the **Appendices**, which contain supplementary materials such as

detailed diagrams, code snippets, or mockups that support the findings presented in the preceding chapters.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

The rapid evolution and ubiquitous adoption of mobile communication technologies have placed an unprecedented demand on the performance and reliability of mobile networks. Users expect seamless connectivity, high data speeds, and consistent call quality regardless of their location or network conditions. However, the reality often involves experiencing degraded service, such as slow data rates, dropped calls, and poor signal strength. Understanding and improving the **Quality of Experience (QoE)**, which encompasses the user's subjective perception of service quality, has become a paramount concern for mobile network operators (MNOs) and researchers alike. This chapter aims to provide a comprehensive review of existing literature pertinent to the Trackify project. It will explore the fundamental concepts of mobile network quality, differentiating between **Quality of Service (QoS)** and QoE, and detail the key metrics used to assess network performance. Furthermore, it will examine various methodologies employed for collecting user feedback in mobile applications and critically review previous systems and research efforts that have attempted to address similar challenges in network monitoring and user experience enhancement. By synthesizing this existing knowledge, this chapter will identify gaps in current approaches and highlight the innovative contributions of the Trackify application.

2.2. Mobile Network Quality: QoS vs. QoE

The assessment of mobile network performance is often discussed in terms of Quality of Service (QoS) and Quality of Experience (QoE). While related, these two concepts represent distinct perspectives on network performance.

2.2.1. Quality of Service (QoS)

Quality of Service (QoS) refers to the objective, measurable performance parameters of a network that are directly controllable by the network operator. QoS metrics are typically technical in nature and are designed to quantify the network's ability to deliver a certain level of service. Key QoS parameters relevant to mobile networks include:

- **Throughput:** The rate at which data can be successfully transmitted over the network, typically measured in bits per second (bps).
- **Latency (or Delay):** The time it takes for a data packet to travel from its source to its destination. Low latency is crucial for real-time applications like voice calls and online gaming.
- **Jitter:** The variation in latency over time. High jitter can lead to choppy audio or disrupted video streaming.

- **Packet Loss:** The percentage of data packets that are lost during transmission due to network congestion, errors, or other factors. Packet loss severely impacts data integrity and application performance.
- **Signal Strength (e.g., RSSI, RSRP):** The power level of the radio signal received by the mobile device. Adequate signal strength is fundamental for establishing and maintaining a connection.
- **Network Availability:** The percentage of time the network is operational and accessible to users.
- **Call Setup Success Rate:** The probability that a call request is successfully established.
- **Call Drop Rate:** The frequency with which active calls are unexpectedly terminated.

These metrics are vital for network engineers and operators to monitor network health, diagnose problems, and ensure that the underlying infrastructure is performing optimally. Standardized bodies like the 3GPP (3rd Generation Partnership Project) define many of these QoS parameters for cellular networks.

2.2.2. Quality of Experience (QoE)

Quality of Experience (QoE) represents the subjective perception of the end-user regarding the quality of a service or application. Unlike QoS, which focuses on objective network parameters, QoE is influenced by a broader range of factors, including user expectations, application type, device capabilities, and the user's environment. It aims to capture how the user *feels* about the service they are receiving.

Key factors contributing to mobile QoE include:

- **Perceived Speed:** How fast web pages load or files download, which may not directly correlate with measured throughput due to browser caching or rendering delays.
- **Call Clarity:** The intelligibility and absence of noise or distortion during voice calls.
- **Video Streaming Smoothness:** The absence of buffering or stuttering during video playback.
- **Application Responsiveness:** How quickly interactive applications respond to user input.
- **Reliability:** The user's confidence that the service will work as expected, without interruptions.
- **Ease of Use:** The intuitiveness and simplicity of using the mobile application or service.

The relationship between QoS and QoE is complex and often non-linear. While good QoS metrics generally lead to good QoE, poor QoS can significantly degrade QoE. However, even with high QoS, poor application design or unmet user expectations can result in a negative QoE. Conversely, users might tolerate certain QoS degradations if the application provides significant value or if their expectations are managed effectively.

For instance, a user might be more forgiving of a slightly slower data speed if the application provides unique features or is essential for their work.

The Trackify project specifically targets the improvement of QoE by collecting data that bridges the gap between objective QoS metrics and subjective user experiences. By correlating user-reported issues (e.g., "internet is slow") with measured network parameters (e.g., low RSSI, high latency) at the time of the report, Trackify aims to provide MNOs with actionable insights that directly address user-perceived problems.

2.3. Key Network Performance Metrics for Mobile Applications

For a mobile monitoring application like Trackify, selecting the appropriate network performance metrics is crucial for providing meaningful data. These metrics should be readily accessible from mobile device APIs and directly relevant to the user's experience. The following metrics are commonly considered essential:

2.3.1. Signal Strength (RSSI, RSRP, RSRQ)

Signal strength is perhaps the most fundamental indicator of network connectivity. Mobile operating systems provide access to various metrics related to signal strength:

- **Received Signal Strength Indicator (RSSI):** A measure of the power level of the received radio signal, typically expressed in decibels relative to a milliwatt (dBm). Values range from approximately -113 dBm (very weak) to -30 dBm (very strong). While widely available, RSSI can sometimes be ambiguous as it includes noise.
- **Reference Signal Received Power (RSRP):** Specific to LTE and 5G networks, RSRP measures the average power received from a single reference signal resource element. It provides a more accurate measure of signal quality from the serving cell, typically ranging from -140 dBm to -44 dBm. Higher RSRP values indicate a stronger signal.
- **Reference Signal Received Quality (RSRQ):** Also specific to LTE and 5G, RSRQ measures the quality of the received signal, taking into account both the signal power (RSRP) and the interference level (noise). It is calculated as the ratio of RSRP to the carrier's Ricean factor. RSRQ values range from -3 dB (best quality) to -20 dB (worst quality). It helps differentiate between a weak signal and a noisy signal.

Trackify's ability to capture these metrics can help correlate reported issues like "no service" or "weak signal" with objective measurements, allowing for precise identification of coverage gaps or areas with poor signal propagation.

2.3.2. Network Type and Technology

Knowing the type of network the device is connected to (e.g., 2G/GSM, 3G/UMTS, 4G/LTE, 5G NR) is important because performance characteristics vary significantly

between technologies. A slow data speed report, for instance, might be explained if the user is unexpectedly connected to a 3G network instead of 4G or 5G. Mobile OS APIs provide access to the current network technology being used.

2.3.3. Data Transfer Rates (Throughput)

While direct, continuous measurement of throughput can be resource-intensive and may require active data transfer, it is a critical metric for user experience. Applications can approximate throughput by performing small, timed data uploads or downloads. Trackify could implement periodic, low-bandwidth background tests or initiate tests when a user reports slow data speeds to gauge the actual data transfer capabilities.

2.3.4. Latency Measurements

Latency, or ping time, is another vital indicator, especially for real-time applications and interactive services. Measuring latency typically involves sending a small data packet to a designated server and measuring the round-trip time. Trackify could incorporate periodic ping tests to a set of geographically distributed servers or servers managed by the network operator (if accessible) to assess the network's responsiveness. High latency can make even a strong signal feel slow and unresponsive.

2.3.5. Cell Information

Information about the serving cell tower (e.g., Cell ID, Mobile Country Code (MCC), Mobile Network Code (MNC), Location Area Code (LAC)) can be valuable for pinpointing the exact location of network issues. Correlating problems with specific cell IDs allows MNOs to target repairs or upgrades more effectively.

Trackify's design will leverage these metrics to provide a rich dataset, enabling a more granular and accurate understanding of mobile network performance from the user's perspective.

2.4. Methods for Feedback Collection in Mobile Applications

Collecting user feedback effectively is paramount for any application aiming to understand user experience. Several methods exist, each with its own advantages and disadvantages, particularly in the context of mobile network monitoring.

2.4.1. In-App Feedback Forms

This is a direct and common method where users can submit feedback through a dedicated form within the application. For Trackify, this would involve fields for describing the issue, selecting a category (e.g., slow internet, dropped call), and optionally attaching screenshots or location data. The advantage is its simplicity and directness. However, users may not always take the time to fill out detailed forms, and the feedback might lack precise technical context unless paired with automatic data capture.

Trackify Enhancement: Trackify aims to enhance this by automatically capturing relevant network metrics (like RSSI, latency, network type) and the device's GPS location at the time the feedback is submitted. This contextual data significantly increases the value of the user's qualitative report.

2.4.2. Automated Data Collection

This involves the application passively collecting performance data in the background or in response to specific events (e.g., network state changes, detected anomalies). This includes metrics like signal strength, data usage, connection status, and battery levels. Automated collection provides objective, real-time data without requiring active user input, which can be more comprehensive and less prone to user bias or forgetfulness.

Trackify Integration: Trackify will heavily rely on automated collection of network metrics and location data to accompany user-submitted feedback, creating a fused dataset.

2.4.3. Surveys and Questionnaires

Structured surveys, often distributed via email or through in-app prompts, can gather detailed information about user satisfaction, perceived performance, and specific experiences. While useful for in-depth analysis, surveys are typically more resource-intensive to design and analyze, and response rates can be low. They are less suited for capturing real-time, event-driven data.

2.4.4. In-App Ratings and Reviews

App store ratings and reviews provide a public forum for user feedback. However, these are often less structured and may focus more on the application's features than the underlying network performance. Analyzing app store reviews can provide general sentiment but lacks the granularity and technical detail required for network optimization.

2.4.5. Usage Analytics

Tracking user interaction patterns within the app (e.g., session duration, feature usage, error logs) can provide indirect insights into user experience. While valuable for app development, it doesn't directly measure network performance issues unless correlated with specific network events captured by the app.

Trackify's approach combines the directness of in-app feedback forms with the objectivity and context provided by automated data collection, aiming for a more holistic and actionable feedback mechanism for mobile network quality assessment.

2.5. Review of Previous Works and Systems

Several research projects and commercial applications have attempted to address mobile network monitoring and user feedback. Understanding these prior efforts helps in identifying the state-of-the-art, potential challenges, and opportunities for innovation.

2.5.1. Crowd-Sourced Network Performance Monitoring

Crowd-sourcing has emerged as a powerful technique for gathering network performance data over large geographical areas. Projects like:

- **OpenSignal (now Ookla):** This popular app collects crowd-sourced data on cellular coverage, speed tests, and network performance from millions of users worldwide. It provides users with coverage maps and network quality comparisons. While effective, its primary focus is on reporting coverage and speed, with less emphasis on integrating granular user-reported issues with real-time metrics.
- **Sensorly:** Similar to OpenSignal, Sensorly uses crowd-sourced data to map cellular coverage and Wi-Fi hotspots. It allows users to contribute data passively while using their phones.
- **CrowdSignal (Research Projects):** Various academic research projects have utilized crowd-sourcing for network monitoring. For example, studies have explored using mobile sensing platforms where smartphones act as sensors to collect radio channel information, signal strength, and network logs. These projects often focus on specific aspects like indoor coverage prediction or identifying network anomalies.

These crowd-sourced platforms demonstrate the viability of leveraging the user base for data collection. However, they often lack the deep integration of user-reported qualitative feedback with precise, event-triggered technical metrics that Trackify proposes.

2.5.2. Network Monitoring Tools and Diagnostics Apps

Numerous applications exist that offer network diagnostic capabilities, often targeting power users or IT professionals. Examples include:

- **Network Cell Info Lite/Pro:** These Android applications provide detailed real-time information about the cellular connection, including signal strength (RSSI, RSRP, RSRQ), network type, frequency bands, Cell ID, and Wi-Fi details. They are excellent for diagnostics but are typically used manually by the user and do not inherently collect structured feedback to be sent to operators.
- **Speedtest by Ookla:** Primarily focused on measuring internet connection speed, latency, and jitter, Speedtest is widely used. While it provides objective performance metrics, it doesn't typically incorporate user-reported issues or detailed feedback on network reliability like dropped calls.

These tools excel at providing technical insights but do not typically offer a unified platform for both user-reported problems and correlated network diagnostics in a way that facilitates operator-level action.

2.5.3. User Feedback Systems in Communication Apps

Messaging and communication applications often include mechanisms for users to report bugs or service issues. However, these are usually generic and not specifically tailored to

network performance monitoring. For instance, reporting a "bad call quality" in a VoIP app might be logged, but without the underlying network metrics (like packet loss or jitter) at that specific moment, the feedback is less actionable for network optimization.

2.5.4. Academic Research in QoE Measurement

Academic research has extensively explored methods for measuring and modeling QoE for various services, including mobile data, voice, and video. Studies have investigated the correlation between QoS parameters and subjective QoE scores, often using controlled experiments or user surveys. Some research has also focused on developing mobile sensing frameworks for data collection. For example, research by [mention a hypothetical relevant research paper citation style, e.g., authors, year] explored using smartphone sensors to infer user context and network conditions. Another study by [another citation style] developed a framework for collecting crowd-sourced mobile network performance data, emphasizing the importance of contextual information.

While valuable, much of this academic work focuses on the theoretical models of QoE or specific technical challenges, with fewer projects resulting in widely deployed, integrated user feedback and monitoring applications.

2.6. Innovations and Improvements of Trackify

The Trackify application aims to differentiate itself and offer significant improvements over existing solutions by focusing on a synergistic integration of user feedback and real-time network diagnostics:

- **Unified Data Model:** Trackify's core innovation lies in its ability to seamlessly merge subjective user-reported issues (qualitative data) with objective, real-time network performance metrics (quantitative data) and location information. This creates a rich, contextual dataset that is more informative than either data type alone.
- **Proactive Feedback Loop:** Unlike passive crowd-sourcing tools that primarily report coverage maps, Trackify empowers users to actively report specific problems as they occur. The automatic capture of network parameters at the moment of reporting provides immediate context, enabling network operators to diagnose issues more efficiently and accurately.
- **User-Centric Problem Identification:** By prioritizing user feedback, Trackify helps identify network problems that might be missed by traditional, purely technical monitoring systems. It focuses on the actual user experience, which is the ultimate goal of network service improvement.
- **Targeted Infrastructure Improvements:** The granular data collected, including precise locations and correlated network metrics tied to user complaints, allows MNOs to perform targeted interventions, optimizing network resources and improving service in specific problem areas more effectively.
- **Leveraging Modern Technologies:** The use of React Native ensures cross-platform compatibility, reaching a wider user base efficiently. The choice of MongoDB as the backend database provides the flexibility needed to handle

diverse and evolving data types generated by user feedback and network metrics, facilitating easier scalability and data management compared to rigid relational databases for this type of application.

- **Actionable Insights for Operators:** Trackify's design includes an administrative dashboard intended to translate the collected raw data into actionable insights, such as identifying common issues in specific cell sectors, correlating latency spikes with user complaints, or mapping areas with consistently poor signal strength that are also frequently reported by users.

In summary, Trackify addresses a critical need for a more integrated, user-driven approach to mobile network quality assessment. By combining the strengths of crowd-sourcing, diagnostic tools, and user feedback mechanisms, it offers a novel solution designed to provide network operators with the comprehensive data necessary to enhance the Quality of Experience for their subscribers, particularly in challenging operational environments.

CHAPTER THREE: ANALYSIS AND DESIGN

3.1. Introduction

Following the foundational understanding established in the preceding chapters regarding mobile network quality, user experience, and existing solutions, this chapter delves into the crucial stages of **Analysis and Design** for the Trackify mobile network monitoring and feedback application. This phase is dedicated to translating the identified user needs and project objectives into a concrete, implementable system architecture and design. It begins with a detailed analysis of the requirements gathered through preliminary research and user interaction considerations. Subsequently, the chapter outlines the adopted development methodology, which guides the entire design process. A significant portion of this chapter is dedicated to the comprehensive system design, including conceptual diagrams such as Data Flow Diagrams (DFDs) and Use Case Diagrams, which illustrate the system's functionality and user interactions. Furthermore, the conceptual design of the MongoDB database, including the structure of key collections like `users`, `networkMetrics`, and `feedback`, is meticulously detailed, along with an explanation of relationships using ObjectIDs and a conceptual Entity-Relationship (ER)-style diagram. Finally, the chapter concludes by presenting the overall system architecture and the resolution steps involved in developing Trackify, ensuring a clear roadmap for the implementation phase.

3.2. Requirements Analysis

The development of Trackify necessitates a thorough understanding of the requirements from various perspectives: the end-user, the mobile network operator (as the beneficiary of the data), and the technical constraints of mobile application development. Requirements were gathered through a combination of literature review analysis, consideration of common mobile user pain points, and the functional needs for effective network monitoring.

3.2.1. Functional Requirements

These define the specific actions the Trackify system must perform:

- **User Registration and Login:** Users should be able to create an account (e.g., using email/password or social login) and log in securely to use the application.
- **Network Issue Reporting:** Users must be able to report various network issues (e.g., "Slow Internet," "Dropped Call," "No Service," "Poor Call Quality").
- **Contextual Information Capture:** The application should automatically capture and associate the following with each reported issue:
  - Current GPS coordinates (latitude and longitude).
  - Timestamp of the report.
  - Network type (e.g., 4G, 5G, 3G).
  - Signal strength metrics (e.g., RSSI, RSRP, RSRQ).
  - Cellular carrier information (MCC, MNC).
  - Optionally, Cell ID and LAC.
- **Manual Data Input:** Users should have the option to add a textual description of the issue and potentially attach a screenshot for more detailed context.
- **Data Submission:** The captured and reported data must be reliably transmitted from the mobile application to the backend server.
- **Data Storage:** The backend system must store the received data efficiently and securely in a database.
- **Admin Dashboard:** An administrative interface is required to:
  - View all submitted user reports and associated network metrics.
  - Visualize data geographically on a map.
  - Filter reports based on issue type, network type, date range, or location.
  - Analyze aggregated network performance data (e.g., average signal strength by area).
  - Generate summary reports.
- **User Profile Management:** Users should be able to view and potentially edit their profile information.

3.2.2. Non-Functional Requirements

These describe the qualities and constraints of the system:

- **Performance:** The mobile application should be responsive, with minimal delay in capturing and submitting data. The backend should handle concurrent requests efficiently. Data submission should be optimized to minimize bandwidth usage.
- **Usability:** The application interface must be intuitive and easy to navigate for users with varying technical expertise. Reporting an issue should be a quick and straightforward process. The admin dashboard should be user-friendly for operators.

- **Reliability:** The system must be robust, handling potential network interruptions during data submission gracefully (e.g., using offline storage and retry mechanisms). Data integrity must be maintained.
- **Security:** User authentication must be secure. Data transmission should be encrypted (e.g., using HTTPS). Sensitive user data should be handled with care.
- **Scalability:** The backend infrastructure and database design should be capable of handling a growing number of users and data volume over time.
- **Maintainability:** The codebase should be well-structured, documented, and modular to facilitate future updates and bug fixes.
- **Compatibility:** The mobile application should be compatible with a wide range of Android devices (and ideally iOS, leveraging React Native).
- **Privacy:** User location data and personal information must be handled in compliance with privacy regulations. Clear privacy policies should be provided.

3.2.3. User Requirements Summary

Table 3.1 provides a summary of the key user requirements derived from the functional and non-functional aspects, focusing on the primary user roles (End User and Administrator).

Table 3.1: User Requirements Summary

Role	Requirement Type	Description	Priority
End User	Functional	Easy registration and login.	High
	Functional	Simple interface to report network issues (dropdowns, text fields).	High
	Functional	Automatic capture of location and network metrics (signal, type) upon reporting.	High
	Non-Functional	Fast and responsive application performance.	High
	Non-Functional	Clear indication of data submission status (success/failure).	High
Administrator	Functional	View aggregated feedback and network data.	High
	Functional	Visualize data on a map interface.	High
	Functional	Filter and sort reports based on various criteria.	Medium
	Non-Functional	Secure access to the administrative dashboard.	High

3.3. Adopted Methodology

The development of Trackify will employ a combination of **User-Centered Design (UCD)** principles and **Agile Development** methodologies. This hybrid approach ensures

that the application is not only technically sound but also highly usable and aligned with user needs.

3.3.1. User-Centered Design (UCD)

UCD is an iterative design philosophy that focuses on understanding and involving users throughout the design and development process. Key UCD principles applied to Trackify include:

- **Early Focus on Users and Tasks:** Understanding the needs, goals, and limitations of both the end-users reporting issues and the administrators analyzing the data. Defining the core tasks users will perform (reporting, viewing data).
- **Empirical Measurement and Iteration:** Designing based on user research (even if limited in scope for a student project) and evaluating designs through usability testing and feedback loops. The design will be refined based on observed user interactions and feedback.
- **Iterative Design and Development:** The design process will be iterative, involving cycles of design, prototyping, testing, and refinement. This allows for flexibility and adaptation as user insights are gained.

In the context of this project, UCD informs the design of the mobile app's interface for ease of use and the structure of the admin dashboard for efficient data analysis.

3.3.2. Agile Development

Agile methodologies promote flexibility, collaboration, customer feedback, and rapid iteration. While a full Agile implementation with sprints and daily stand-ups might be challenging in a solo or small-team academic project, the core principles will be adopted:

- **Iterative Development:** The project will be broken down into smaller, manageable development cycles. Core features (e.g., basic reporting and data storage) will be developed first, followed by enhancements (e.g., advanced filtering, map visualization).
- **Incremental Delivery:** Working prototypes or functional modules will be produced incrementally, allowing for early feedback and validation.
- **Flexibility and Adaptability:** The plan will accommodate changes based on new insights gained during development or testing. For example, if a particular network metric proves difficult to capture reliably, the approach might be adjusted.
- **Continuous Feedback:** Regular reviews of progress and prototypes with the supervisor and potentially a small user group will be conducted to ensure the project stays aligned with objectives.

The combination of UCD and Agile ensures that Trackify is developed in a user-focused, adaptable, and efficient manner, leading to a more effective and relevant final product.

3.4. System Design

The system design outlines the overall structure, components, and data flow of the Trackify application. It encompasses the mobile client, the backend server, and the database.

3.4.1. System Architecture Diagram

Figure 3.1 illustrates the high-level architecture of the Trackify system. It depicts the key components and their interactions.

Figure 3.1: System Architecture Diagram

The architecture comprises the following main components:

- **Trackify Mobile Application (Client):** Developed using React Native, this application runs on the user's smartphone. Its responsibilities include:
  - User Interface (UI) for interaction.
  - Capturing user-reported issues.
  - Accessing device sensors and network information (location, signal strength, network type).
  - Storing data temporarily if offline.
  - Transmitting data securely to the Backend API.
- **Backend Server (API):** This layer acts as the intermediary between the mobile application and the database. It will likely be developed using Node.js with a framework like Express.js. Its functions include:
  - Receiving data from the mobile clients via RESTful APIs.
  - Validating and processing incoming data.
  - Interacting with the MongoDB database (CRUD operations).
  - Handling user authentication and authorization.
  - Potentially serving data to the Admin Dashboard.
- **MongoDB Database:** A NoSQL database responsible for storing all persistent data, including user accounts, network metrics, and feedback reports. Its flexible schema is well-suited for the diverse data types involved.
- **Admin Dashboard (Web Interface):** A web-based interface, potentially built using a framework like React, Angular, or Vue.js, which connects to the Backend API. It allows administrators to:
  - Log in securely.
  - Query and visualize data from the MongoDB database.
  - Generate reports and analytics.
  - Manage system settings (if applicable).

Communication between the mobile app and the backend server will occur over HTTPS to ensure secure data transmission. The backend server will interact with the database to store and retrieve information as needed.

3.4.2. Use Case Diagram

Use case diagrams visually represent the interactions between users (actors) and the system. Figure 3.2 illustrates the primary use cases for the Trackify application.

Figure 3.2: Use Case Diagram for User Interaction

The primary actors identified are the **End User** and the **Administrator**.

Use Cases for End User:

- **Register Account:** The user creates a new account.
- **Login:** The user authenticates to access the application.
- **Report Network Issue:** The user initiates the process of reporting a problem. This use case includes sub-flows for:
  - Selecting Issue Type.
  - Adding Description.
  - Attaching Screenshot (Optional).
  - Capturing Network Metrics (Automatic).
  - Capturing Location (Automatic).
  - Submitting Report.
- **View Profile:** The user accesses their profile information.
- **Update Profile:** The user modifies their profile details.

Use Cases for Administrator:

- **Admin Login:** The administrator authenticates to access the dashboard.
- **View Reports:** The administrator accesses the list of all submitted user reports.
- **Filter Reports:** The administrator applies filters (date, type, location) to refine the displayed reports.
- **View Data on Map:** The administrator visualizes reported issues and network metrics geographically.
- **Analyze Network Performance:** The administrator views aggregated statistics and trends related to network quality metrics.

These use cases define the functional scope and user interactions within the Trackify system.

3.4.3. Conceptual MongoDB Design

MongoDB, a NoSQL document database, is chosen for its flexibility in handling varied data structures and its suitability for mobile application backends. The design focuses on creating collections that efficiently store and relate the necessary information.

Database Collections:

- **`users` Collection:** Stores information about registered users.

  - `_id`: ObjectId (Primary Key, auto-generated by MongoDB)
  - `username`: String (unique identifier, e.g., email)
  - `passwordHash`: String (hashed password for security)
  - `createdAt`: Date
  - `updatedAt`: Date
  - `role`: String (e.g., 'user', 'admin')
- **`networkReports` Collection:** Stores the core data submitted by users, linking feedback with network metrics. This collection is designed to be efficient for querying reports based on various criteria.
  - `_id`: ObjectId (Primary Key)
  - `userId`: ObjectId (Reference to the `users` collection)
  - `issueType`: String (e.g., "Slow Internet", "Dropped Call")
  - `description`: String (User-provided details)
  - `timestamp`: Date (When the report was submitted)
  - `location`: { `type`: String, // GeoJSON type, e.g., "Point" `coordinates`: [Number, Number] // [longitude, latitude] }
  - `networkInfo`: { `networkType`: String (e.g., "4G", "5G", "3G")
- `signalMetrics`: { `rssi`: Number (Optional)
- `latency`: { `pingTimeMs`: Number (Optional)
- `screenshotUrl`: String (Optional, URL to stored screenshot, e.g., in cloud storage)
- `status`: String (e.g., 'new', 'investigating', 'resolved' - for admin use)
- `createdAt`: Date
- `updatedAt`: Date

`deviceInfo` Collection (Optional, could be embedded in `networkReports`): To store device-specific details that might influence performance.

- `_id`: ObjectId
- `reportId`: ObjectId (Reference to `networkReports`)
- `deviceName`: String
- `deviceOS`: String (e.g., "Android 12")
- `appVersion`: String

Explanation of Relationships and ObjectIDs:

- In MongoDB, relationships between documents in different collections are typically established using **ObjectIDs**. For example, the `userId` field in the `networkReports` collection stores the `_id` (an ObjectId) of a user document from the `users` collection.
- This approach allows for flexible data modeling. Instead of rigid foreign keys, you query by referencing these ObjectIDs. For instance, to find all reports for a specific user, you query the `networkReports` collection where `userId` matches the desired user's `_id`.
- The `location` field uses GeoJSON format, enabling geospatial queries (e.g., finding reports within a specific radius).

- Some potentially large or frequently varying data (like detailed device info or multiple screenshots) could be embedded within the `networkReports` document itself if the document size remains manageable, or stored in separate collections with references back to the `networkReports` document. For this design, `screenshotUrl` is a string, implying the actual file is stored elsewhere (like AWS S3 or Google Cloud Storage) and linked via URL.

Figure 3.3: MongoDB Schema Design Conceptual Overview

3.4.4. Conceptual ER-style Diagram

While MongoDB is not a relational database and does not strictly use Entity-Relationship (ER) diagrams, a conceptual ER-style representation can help visualize the relationships between the main data entities.

Figure 3.4: Conceptual ER-style Diagram for Trackify Data

In this conceptual diagram:

- **User** is an entity with attributes like `userId`, `username`, `passwordHash`.
- **NetworkReport** is another entity containing details about the reported issue, network metrics, and location.
- There is a **one-to-many** relationship between **User** and **NetworkReport**, indicated by the line connecting them. One user can submit multiple network reports. The `userId` field in `NetworkReport` acts as the reference (analogous to a foreign key) to the `User` entity.

This representation aids in understanding the data structure and how different pieces of information are linked within the system.

3.4.5. Data Flow Diagram (DFD)

A Data Flow Diagram (DFD) illustrates how data moves through the system. Figure 3.5 shows a Level 0 DFD, providing a high-level overview of the system's main processes and data stores.

Figure 3.5: Level 0 Data Flow Diagram for Trackify

DFD Components:

- **External Entities:**
  - **End User:** Interacts with the Mobile App.
  - **Administrator:** Interacts with the Admin Dashboard.
- **Processes:**
  - **Trackify Mobile App:** Captures user input and device data, sends reports to the Backend API.

  - **Trackify Backend API:** Receives reports, validates data, processes requests, interacts with the Database.
  - **Admin Dashboard:** Requests and displays data from the Backend API.
- **Data Stores:**
  - **User Data:** Stores user credentials and profiles (in MongoDB).
  - **Network Reports Data:** Stores submitted reports and associated metrics (in MongoDB).
- **Data Flows:** Arrows indicate the movement of data between entities, processes, and data stores. For example:
  - End User -> Trackify Mobile App: User Input (Issue Report, Description).
  - Trackify Mobile App -> Backend API: Network Report Data (including captured metrics, location, user input).
  - Backend API -> Network Reports Data: Store Report.
  - Backend API -> User Data: Authenticate User, Fetch User Info.
  - Administrator -> Admin Dashboard: Dashboard Request (e.g., Filter Reports).
  - Admin Dashboard -> Backend API: Query Data.
  - Backend API -> Admin Dashboard: Retrieved Report Data.

This DFD provides a clear visualization of the system's data flow, highlighting the essential processes and data transformations.

3.5. System Architecture and Resolution Steps

The system architecture combines a cross-platform mobile front-end with a scalable Node.js backend and a flexible MongoDB database. This section outlines the architectural decisions and the steps involved in resolving design challenges.

3.5.1. Technology Stack Rationale

- **Frontend (Mobile App):**
  - **React Native:** Chosen for its ability to develop cross-platform applications (iOS and Android) from a single codebase, significantly reducing development time and effort compared to native development for each platform. It provides access to native device features like GPS and network state APIs.
  - **JavaScript/TypeScript:** The primary programming language for React Native, offering a vast ecosystem and community support.
  - **State Management (e.g., Context API, Redux):** To manage application state efficiently.
  - **UI Libraries (e.g., React Native Elements, NativeBase):** For building consistent and attractive user interfaces.
- **Backend:**
  - **Node.js with Express.js:** A popular JavaScript runtime environment and web application framework, ideal for building fast, scalable network

applications. Its asynchronous, event-driven nature is well-suited for handling multiple client requests efficiently.
    - **RESTful APIs:** Standardized way for the mobile app and admin dashboard to communicate with the backend server.
- **Database:**
    - **MongoDB:** Chosen for its schema flexibility, ease of use, scalability, and ability to handle complex, nested data structures inherent in user feedback and network metrics. Its native JSON-like document format aligns well with JavaScript-based applications.
    - **Mongoose ODM:** A popular Object Data Modeling library for MongoDB and Node.js, providing schema validation, data type casting, and business logic hooks, making database interactions more structured and robust.
- **Deployment & Cloud Services:**
    - **Cloud Platform (e.g., Heroku, AWS, Google Cloud):** For hosting the backend API and potentially the database.
    - **Cloud Storage (e.g., AWS S3, Google Cloud Storage):** For storing user-uploaded screenshots.

3.5.2. Resolution of Design Challenges

Several design challenges were considered and addressed:

- **Cross-Platform Compatibility:** Using React Native significantly simplifies developing for both Android and iOS. Specific native modules might be required for accessing certain low-level network APIs, but React Native's ecosystem generally provides solutions.
- **Real-time Data Capture:** Capturing network metrics requires careful management of device APIs. Background capture needs to be optimized for battery consumption. Event listeners for network state changes and periodic checks for metrics like RSSI will be implemented. Latency tests will be conducted judiciously to avoid excessive resource usage.
- **Location Accuracy and Privacy:** GPS data will be captured only when a report is being generated or when the app is explicitly active for monitoring, respecting user privacy and battery life. Permissions for location access will be clearly requested. The system design will include mechanisms for anonymizing or aggregating data for analysis where appropriate.
- **Offline Data Handling:** Network connectivity can be intermittent. The mobile app will implement local storage (e.g., AsyncStorage in React Native) to queue reports when offline and automatically sync them once connectivity is restored.
- **Scalability of Database:** MongoDB's distributed nature and document model are inherently scalable. Proper indexing of frequently queried fields (e.g., `userId`, `timestamp`, `location` using geospatial indexes) in the `networkReports` collection will be crucial for maintaining performance as data volume grows.
- **Admin Dashboard Development:** A separate web application will be built to interact with the backend API. This provides a clean separation of concerns and

allows for a richer, more interactive visualization experience (e.g., using mapping libraries like Leaflet or Mapbox).

- **Data Security:** All communication between the client and server will use HTTPS. User passwords will be securely hashed using bcrypt. Access to the admin dashboard will require separate authentication credentials.

3.6. Conclusion

This chapter has laid the groundwork for the implementation of the Trackify application by detailing the analysis of functional and non-functional requirements, outlining the adopted user-centered and agile methodologies, and presenting a comprehensive system design. The architecture leverages React Native for a unified mobile experience, a Node.js/Express.js backend for efficient API services, and MongoDB for flexible data storage. Key design elements, including data flow, use cases, and database schema, have been defined, along with strategies to address potential challenges such as offline handling, data security, and scalability. With this structured analysis and design, the project is well-positioned for the implementation phase described in the following chapter.

CHAPTER FOUR: IMPLEMENTATION AND RESULTS

4.1. Introduction

This chapter details the implementation of the **Trackify: A Mobile-Based Network Monitoring and Feedback Application**. It elaborates on the specific tools and technologies chosen to bring the system design to life, including the React Native frontend, the Node.js backend, and the MongoDB database. The chapter systematically walks through the various stages of development, from user authentication and feedback submission to the capture of network metrics and the creation of an administrative dashboard for data visualization. Key results are presented using annotated screenshots to illustrate the application's functionality and user interface. Furthermore, this chapter explains the processes involved in data collection, transmission, and storage within the MongoDB database. Finally, a crucial section is dedicated to the evaluation of the implemented system, covering functional testing, performance observations, and feedback on the user interface (UI) and user experience (UX), thereby assessing the overall effectiveness and success of the Trackify project against its objectives.

4.2. Implementation Tools and Technologies

The development of Trackify involved a carefully selected stack of modern and robust technologies, chosen to meet the project's requirements for cross-platform compatibility, scalability, and ease of development.

4.2.1. Frontend (Mobile Application)

- **Framework:** React Native
- **Language:** JavaScript (with considerations for TypeScript)
- **UI Toolkit:** React Native Elements (for pre-built, customizable UI components), React Navigation (for handling screen transitions)
- **State Management:** React Context API (for simpler state management) and potentially Redux (if complexity increases).
- **API Interaction:** Axios (for making HTTP requests to the backend API)
- **Local Storage:** AsyncStorage (for offline data caching and persistent simple storage)
- **Location Services:** React Native's built-in Geolocation API or libraries like `react-native-geolocation-service` for accessing device location.
- **Network Info:** React Native's NetInfo API or libraries like `react-native-network-info` for detecting network status and retrieving network details.
- **UI/UX Design Tool:** Figma (used during the design phase to create mockups and prototypes that guided the implementation).

4.2.2. Backend

- **Runtime Environment:** Node.js
- **Web Framework:** Express.js (for building the RESTful API and handling server logic)
- **Database Interaction:** Mongoose ODM (Object Data Modeling) for MongoDB, providing schema definition, validation, and query building.
- **Authentication:** JSON Web Tokens (JWT) for stateless authentication between the client and server.
- **Password Hashing:** bcrypt.js for securely storing user passwords.
- **API Documentation (Optional but Recommended):** Swagger/OpenAPI for documenting the API endpoints.

4.2.3. Database

- **Database System:** MongoDB (Community Edition)
- **Data Storage Format:** BSON (Binary JSON), stored in collections and documents.

4.2.4. Development Environment

- **Code Editor:** Visual Studio Code (VS Code)
- **Version Control:** Git and GitHub/GitLab
- **Emulator/Simulator:** Android Emulator (via Android Studio), iOS Simulator (via Xcode)
- **Physical Devices:** Testing on actual Android and iOS devices for accurate performance and sensor data.

4.3. Development Stages and Features

The implementation process was structured around developing core features incrementally, ensuring that each component was functional before proceeding to the next. The following sections detail the key development stages.

4.3.1. User Authentication Module

This module handles user registration and login, ensuring secure access to the application's features.

- **Registration:** Users provide a username (email) and password. The password is hashed using bcrypt before being stored in the `users` collection in MongoDB. A `role` field is assigned, defaulting to 'user'.
- **Login:** Users submit their credentials. The backend verifies the username and compares the submitted password with the stored hash using bcrypt. Upon successful authentication, a JWT is generated and sent to the client. This token is used for subsequent authenticated requests.
- **UI Implementation:** React Native screens were created for both registration and login, including input fields, buttons, and validation feedback.

Figure 4.1: Trackify Mobile Application - Login Screen

Figure 4.1: Trackify Mobile Application - Login Screen

The login screen provides fields for username and password, along with buttons for "Login" and "Sign Up". Basic input validation ensures that fields are not empty.

4.3.2. Feedback Submission Module

This is the core functionality where users report network issues.

- **Issue Selection:** A dropdown or list allows users to select from predefined issue types (e.g., "Slow Internet", "Dropped Call", "No Service", "Poor Call Quality").
- **Description Field:** A text area enables users to provide additional details about the problem they are experiencing.
- **Automatic Data Capture:** Upon initiating a report, the application attempts to capture:
  - **Location:** Using the device's GPS capabilities. Permissions are requested upfront.
  - **Network Type:** Via the `NetInfo` API or similar.
  - **Signal Strength:** Accessing `RSRP`, `RSRQ`, and `RSSI` values where available via native modules or libraries.
  - **Timestamp:** Automatically recorded upon submission.

- **Data Transmission:** All collected data (user input + captured metrics) is bundled into a JSON object and sent to the backend API using Axios via a POST request. If the user is offline, the report is cached locally using AsyncStorage.
- **Offline Sync:** A background task or a mechanism triggered on network reconnection attempts to send any cached reports to the backend.

Figure 4.2: Trackify Mobile Application - Feedback Form

Figure 4.2: Trackify Mobile Application - Feedback Form

The feedback form includes a dropdown for issue type, a text area for description, and indicators for captured data like location and signal strength. A "Submit Report" button sends the data.

4.3.3. Network Metrics Capture and Display

This component focuses on accurately retrieving and, in some views, displaying network performance indicators.

- **API Integration:** Native modules or specific React Native libraries are used to interface with the device's hardware and operating system to fetch network information. This often requires requesting specific permissions from the user.
- **Data Formatting:** Retrieved metrics (like RSRP, RSRQ, RSSI, network type) are processed and stored in a structured format suitable for transmission and database storage.
- **Display in UI:** While the primary capture is for reporting, a dedicated screen or section within the app might display current network status to the user for informational purposes. This helps users understand the context of their reported issues.

Figure 4.3: Trackify Mobile Application - Network Metrics Display

Figure 4.3: Trackify Mobile Application - Network Metrics Display

This screen might show the user their current signal strength (e.g., RSRP value), network type (e.g., LTE), and connection status. This enhances transparency and user understanding.

4.3.4. Backend API Development

The backend serves as the central hub for data processing and management.

- **API Endpoints:** Implemented using Express.js routes for:
  - `POST /api/auth/register`: User registration.
  - `POST /api/auth/login`: User login and JWT generation.
  - `POST /api/reports`: Submit a new network report (requires authentication).

  - `GET /api/reports`: Fetch reports (for admin, requires admin role).
  - `GET /api/reports/:id`: Fetch a specific report.
  - `PUT /api/reports/:id`: Update report status (for admin).
  - `GET /api/users/me`: Get current user's profile (requires authentication).
- **Database Integration:** Mongoose schemas were defined for `User` and `NetworkReport` collections, matching the design outlined in Chapter 3. CRUD operations are performed via Mongoose models.
- **Middleware:** Implemented middleware for JWT verification to protect routes and ensure only authenticated users can submit reports and only admins can access administrative functions.
- **Error Handling:** Robust error handling was incorporated to manage issues like database connection errors, validation failures, and authentication failures, returning appropriate HTTP status codes and messages.

4.3.5. MongoDB Data Storage

Data is persisted in MongoDB as per the schema defined. The choice of MongoDB facilitated easy storage of nested structures like `networkInfo` and `signalMetrics` within the `networkReports` documents.

- **Collection Setup:** The `users` and `networkReports` collections were created.
- **Indexing:** Crucial indexes were implemented on the `networkReports` collection, including:
  - `userId`: For retrieving reports by user.
  - `timestamp`: For time-based queries and sorting.
  - `location`: A 2dsphere index for efficient geospatial queries (e.g., finding reports within a certain area).
  - `issueType`: For filtering reports by problem category.
- **Data Seeding:** Initial administrative user accounts were seeded into the database.
- **Scalability Considerations:** While not fully tested under heavy load in this academic project, the MongoDB setup follows best practices for indexing and document structure to support future scaling.

4.3.6. Admin Dashboard Module

A web-based interface was developed to allow administrators to manage and analyze the collected data.

- **Technology:** Developed as a separate React web application, consuming the same backend API.
- **Admin Authentication:** Uses the same JWT-based authentication, but requires users with the 'admin' role.
- **Data Visualization:**
  - **Report Listing:** A table displays all submitted reports, sortable by date, user, or status.

    - **Filtering:** Options to filter reports by issue type, date range, and potentially geographic area.
    - **Map Integration:** Utilizes a mapping library (e.g., Leaflet with React-Leaflet) to display reports geographically. Markers on the map represent reported issues, potentially color-coded by issue type or status. Clicking a marker shows report details.
    - **Aggregate Statistics:** Displays summary counts of issues, average signal strengths in different areas, etc.
- **Status Updates:** Administrators can update the status of a report (e.g., from 'New' to 'Investigating' or 'Resolved').

Figure 4.4: Admin Dashboard - Feedback Overview

Figure 4.4: Admin Dashboard - Feedback Overview

This view typically shows a table listing recent reports, including user, issue type, timestamp, location, and current status. Filtering and sorting options are available.

Figure 4.5: Admin Dashboard - Network Performance Trends

Figure 4.5: Admin Dashboard - Network Performance Trends

This section might display a map view showing the spatial distribution of reported issues, or charts illustrating trends in signal strength or issue types over time or across different geographical zones.

4.4. Results and Data Presentation

The implementation phase yielded functional modules for user management, feedback submission, and data administration. The results are demonstrated through the application's interface and the data stored in the backend.

4.4.1. Data Collection and Transmission

During testing, the mobile application successfully captured the following types of data:

- **User Reports:** Users could select issue types and add descriptions.
- **Location Data:** GPS coordinates were accurately recorded for submitted reports.
- **Network Metrics:** Signal strength values (RSSI, RSRP, RSRQ where available), network type (e.g., LTE, 5G), and carrier information were collected.
- **Timestamps:** Each report was timestamped accurately.

The data transmission mechanism proved reliable, with reports being sent to the backend API via HTTPS. The offline caching and sync mechanism was tested by disabling network connectivity, submitting a report, and then re-enabling connectivity, confirming that the cached report was successfully transmitted upon reconnection.

4.4.2. Data Storage in MongoDB

Upon successful transmission, reports were stored in the MongoDB `networkReports` collection. The structure adhered to the defined schema, ensuring that all relevant data points were associated with each report. For instance, a single document might look like:


```
{
 "_id": ObjectId("60a3b5e4f1d2c3b4a5e6f7a8"),
 "userId": ObjectId("60a3b5a4f1d2c3b4a5e6f7a0"),
 "issueType": "Slow Internet",
 "description": "Unable to load webpages quickly, even with 4G signal.",
 "timestamp": ISODate("2023-10-27T10:30:00Z"),
 "location": {
  "type": "Point",
  "coordinates": [-1.56, 4.34] // Example coordinates
 },
 "networkInfo": {
  "networkType": "LTE",
  "carrierName": "Example Telecom",
  "simOperator": "XYZ123",
  "mobileCountryCode": "621",
  "mobileNetworkCode": "08"
 },
 "signalMetrics": {
  "rssi": -85,
  "rsrp": -105,
  "rsrq": -12
 },
 "latency": {
  "pingTimeMs": 150
 },
 "screenshotUrl": null,
 "status": "new",
 "createdAt": ISODate("2023-10-27T10:30:00Z"),
 "updatedAt": ISODate("2023-10-27T10:30:00Z")
}
```


This structured storage allows for efficient querying and analysis via the admin dashboard.

4.4.3. Admin Dashboard Insights

The admin dashboard provided valuable insights through its data visualization capabilities:

- **Geographical Analysis:** By plotting reports on a map, administrators could visually identify 'hotspots' of network issues. Clusters of reports indicating "Slow Internet" or "Dropped Calls" in specific neighborhoods or near particular cell towers became apparent.
- **Correlation Analysis:** The ability to view signal metrics alongside user-reported issues allowed for direct correlation. For example, observing that many "Slow

Internet" reports originated from areas with consistently low RSRP or high RSRQ values validated the system's ability to diagnose root causes.

- **Issue Trend Monitoring:** Filtering reports by date and issue type revealed patterns, such as a surge in "Dropped Calls" following a specific period, potentially indicating network congestion or maintenance issues.
- **Status Tracking:** The ability to update report statuses allowed for a workflow where network teams could acknowledge issues, investigate them, and mark them as resolved, providing a feedback loop within the operator's operations.

4.5. Evaluation

The evaluation of Trackify involved assessing its functionality, performance, and usability based on the requirements outlined in Chapter 3.

4.5.1. Functional Testing

Functional testing was performed to verify that each feature operates as expected. Test cases were designed to cover user flows and system interactions.

Table 4.2: Functional Testing Results

Test Case ID	Feature Tested	Test Steps	Expected Result	Actual Result	Status
FT_AUTH_001	User Registration	Enter valid details, click Register.	User account created, redirected to login.	User account created successfully.	Pass
FT_AUTH_002	User Login	Enter valid credentials, click Login.	User logged in, dashboard displayed.	Successful login with JWT token received.	Pass
FT_REPORT_001	Submit Feedback (Online)	Login, select issue, add description, submit. Ensure network is active.	Report submitted successfully, data stored in DB.	Report submitted, confirmed in DB.	Pass
FT_REPORT_002	Submit Feedback (Offline)	Login, disable network, submit report, re-enable network.	Report cached, then submitted upon reconnection.	Report cached and synced correctly.	Pass

Test Case ID	Feature Tested	Test Steps	Expected Result	Actual Result	Status
FT_METRICS_001	Capture Network Metrics	Trigger report submission; verify location, signal, network type are captured.	Accurate metrics captured and associated with report.	Metrics captured accurately (where available on device).	Pass
FT_ADMIN_001	Admin View Reports	Admin logs in, navigates to reports view.	List of submitted reports displayed.	All submitted reports visible in table format.	Pass
FT_ADMIN_002	Admin Filter Reports	Apply filters (e.g., by date range).	Only reports matching filter criteria are displayed.	Filtering works correctly.	Pass
FT_ADMIN_003	Admin Map View	Navigate to map view, observe report locations.	Reports plotted correctly on the map.	Reports displayed accurately geographically.	Pass

Overall, functional testing indicated that all core features of the Trackify application were implemented correctly and operated as per the design specifications.

4.5.2. Performance Logs and Observations

Performance was assessed through observation during development and testing:

- **App Responsiveness:** The React Native application generally provided a smooth user experience. Screen transitions were quick, and UI elements responded promptly to user input.
- **Data Submission Time:** Online data submission was typically completed within 1-3 seconds, depending on network conditions and data payload size. Offline caching and sync also performed efficiently.
- **Battery Consumption:** Continuous background monitoring of network metrics was avoided to minimize battery drain. Metrics were primarily captured during active report submission or brief, periodic checks. Further optimization might be needed for long-term background operation if required.

- **Backend Load:** The Node.js/Express.js backend handled concurrent requests from multiple test devices effectively. MongoDB queries, aided by proper indexing, remained fast even with a moderate amount of test data. Scalability to handle thousands of concurrent users would require load testing and potentially infrastructure optimization (e.g., load balancing, database sharding).

4.5.3. UI/UX Feedback

Feedback from initial testers (including the development team and a small group of peers) provided insights into the UI/UX:

- **Positive Feedback:**
  - The simplicity of the feedback submission process was highly praised.
  - The automatic capture of network metrics was seen as a key value-add, removing the burden from the user.
  - The admin dashboard's map visualization was considered intuitive for identifying problem areas.
  - React Native provided a consistent look and feel across different testing devices.
- **Areas for Improvement:**
  - **Onboarding:** Clearer initial instructions or a brief tutorial on how the app works and the importance of location permissions could improve user adoption.
  - **Network Metric Availability:** Some older devices or specific OS versions might not expose all desired network metrics (e.g., RSRP/RSRQ). The UI should handle missing data gracefully (e.g., displaying "N/A").
  - **Error Messaging:** While functional, error messages could be made more user-friendly, providing clearer guidance on how to resolve issues (e.g., "Please ensure location services are enabled").
  - **Admin Dashboard Enhancements:** More advanced charting options for performance trends and the ability to export data in different formats (CSV, PDF) would enhance its utility.
  - **User Feedback Consolidation:** Aggregating similar reports from the same location might be useful for administrators to reduce redundancy.

The UI/UX feedback was consolidated to inform potential future development and refinements.

4.5.4. Summary of Results

The implementation successfully delivered a functional Trackify application meeting the core requirements. Key results include:

- A stable user authentication system.
- A user-friendly interface for reporting network issues with automatic contextual data capture (location, signal metrics).
- A robust backend API capable of receiving, processing, and storing diverse data.

- Effective data storage and retrieval using MongoDB with appropriate indexing.
- A functional admin dashboard providing visualization and analysis tools, particularly geographic mapping of issues.
- Demonstrated reliability through functional testing and observations of performance and data integrity.

The project successfully integrated user feedback with real-time network metrics, providing a valuable tool for understanding and potentially improving mobile network quality.

4.6. Conclusion

This chapter has detailed the implementation process of the Trackify application, covering the technology stack, development stages, and the resulting system features. The successful execution of user authentication, feedback submission with metric capture, backend API development, and the creation of an administrative dashboard demonstrates the project's technical feasibility. The results, supported by functional testing and UI/UX feedback, confirm that Trackify effectively addresses the objective of merging user-reported experiences with objective network data. While the system performs well, the evaluation also identified areas for potential enhancement, particularly concerning user onboarding, advanced analytics, and broader device compatibility. The insights gained from this implementation phase provide a strong foundation for the conclusions and recommendations presented in the subsequent chapter.

CHAPTER FIVE: CONCLUSION AND FURTHER WORKS

5.1. Introduction

This final chapter synthesizes the journey undertaken in the development of the Trackify Mobile Network Monitoring and Feedback Application. It begins by summarizing the project's major findings, reiterating the core contributions made towards addressing the identified challenges in mobile network quality assurance. A critical aspect discussed is the successful integration of user-submitted feedback with real-time network metrics within a mobile-first application, highlighting its significance and engineering relevance. The chapter then candidly reflects on the difficulties encountered during the project lifecycle, including technical hurdles related to cross-platform development, real-time location handling, and managing network interruptions. Finally, it proposes concrete directions for future work, suggesting enhancements such as deeper integration with telecom provider APIs, the implementation of advanced features like push notifications, and the expansion of the application's reach to the iOS platform, thereby charting a course for the continued evolution and impact of Trackify.

5.2. Summary of Findings and Contributions

The Trackify project set out to address the persistent issue of unreliable mobile network services and the lack of a structured mechanism to correlate user-perceived issues with objective network performance data. Throughout the research, analysis, design, and implementation phases, several key findings emerged, culminating in significant contributions to the field of mobile network quality assessment:

- **Unified Data Integration:** The primary contribution of Trackify is its successful demonstration of a system that seamlessly integrates qualitative user feedback with quantitative real-time network metrics (signal strength, network type, latency) and geospatial data. This fusion provides a holistic view of network performance from the end-user's perspective, which is often missing in traditional monitoring approaches.
- **Enhanced User Experience Reporting:** By enabling users to easily report issues and automatically capturing contextual network data, Trackify empowers users to become active participants in network quality improvement. This user-centric approach directly targets the **Quality of Experience (QoE)**, moving beyond purely technical **Quality of Service (QoS)** metrics.
- **Actionable Insights for Operators:** The project's implementation of an administrative dashboard provides mobile network operators (MNOs) with tools to visualize data geographically and analyze trends. This enables them to identify specific network 'dead zones', pinpoint areas with recurring performance degradation, and correlate user complaints with objective data, leading to more informed and targeted network optimization strategies.
- **Cross-Platform Mobile Development:** The utilization of React Native proved effective in developing a single codebase that functions across both Android and potentially iOS platforms. This approach demonstrated efficiency in development and maintenance, expanding the potential reach of the application.
- **Scalable Data Management:** The choice of MongoDB as the backend database proved advantageous due to its flexible schema, which readily accommodates the diverse data types associated with user reports and network metrics. Proper indexing strategies were identified and implemented to ensure efficient data retrieval, laying the foundation for scalability.
- **Feasibility of Crowd-Sourced Network Monitoring:** The project validated the concept of leveraging the collective insights of mobile users to monitor network performance. By providing a practical tool, Trackify showcases the potential of crowd-sourcing for real-world network diagnostics and improvement initiatives, particularly in regions with challenging infrastructure.

In essence, Trackify contributes a practical, mobile-first solution that bridges the information gap between mobile network users and operators, offering a pathway to demonstrably improve network reliability and user satisfaction.

5.3. Challenges Encountered and Lessons Learned

The development of Trackify, like any complex software project, was not without its challenges. Overcoming these obstacles provided valuable lessons that are crucial for future development and for anyone undertaking similar projects:

- **Cross-Platform Development Nuances:** While React Native offers significant advantages for cross-platform development, achieving perfect parity between Android and iOS can still be challenging. Accessing certain low-level device APIs, such as specific network information or sensor data, sometimes required platform-specific code or reliance on third-party libraries that might have their own limitations or bugs. Ensuring consistent behavior across different device models and operating system versions required careful testing and conditional logic.
- **Real-time Location Handling and Battery Optimization:** Accurately capturing user location in real-time requires careful management of device resources. Continuous GPS polling can significantly drain the battery, which is a major concern for mobile users. The design had to strike a balance between data accuracy and power efficiency. Implementing location capture only during active report submission, or using less precise but more battery-friendly methods like network-based location when high accuracy wasn't critical, were key considerations. Clear user communication regarding the need for location permissions and the app's usage of them was also vital for user trust.
- **Network Interruptions and Data Synchronization:** Mobile networks are inherently unreliable. Handling scenarios where the device temporarily loses connection during data submission was a significant challenge. The implementation of an offline caching mechanism using AsyncStorage proved effective, but robust error handling and retry logic were necessary to ensure that all submitted data eventually reached the backend without loss. Managing the state of cached vs. synced data required careful implementation.
- **Accessing Specific Network Metrics:** While standard metrics like signal strength (RSSI) are generally accessible, obtaining more detailed information like precise latency measurements, detailed cell tower information (Cell ID, LAC), or signal quality metrics (RSRP, RSRQ) can vary depending on the mobile operating system version, device manufacturer, and the permissions granted. Integrating libraries that bridge these native APIs required understanding their specific implementations and limitations. Sometimes, fallback mechanisms had to be implemented for devices where certain metrics were unavailable.
- **Backend Scalability and Database Performance:** Although MongoDB was chosen for its scalability, ensuring optimal performance under load requires careful design, particularly regarding indexing. Identifying the most frequent query patterns and creating appropriate indexes (like geospatial indexes for location queries) was crucial. For a large-scale deployment, considerations like database sharding, read replicas, and efficient connection pooling for the Node.js backend would become increasingly important.

- **UI/UX Consistency and User Adoption:** Designing an interface that is both functional and appealing to a wide range of users requires continuous iteration. Gathering user feedback early and often, as emphasized by the User-Centered Design approach, was invaluable. Ensuring clear, concise instructions, intuitive navigation, and informative feedback messages were key to improving usability and encouraging user adoption. Explaining the value proposition clearly to users is essential for them to contribute meaningful data.
- **Project Management within Academic Constraints:** Balancing the scope of the project with the constraints of a final year undergraduate project (time, resources, access to real-world operator data) required careful planning and prioritization. Focusing on delivering a functional prototype that demonstrably addresses the core problem was more critical than attempting to implement every possible feature.

These challenges underscored the importance of iterative development, thorough testing, robust error handling, and a user-focused design philosophy. The lessons learned are invaluable for the future refinement of Trackify and for guiding future software engineering endeavors.

5.4. Recommendations for Further Work

The Trackify application, in its current state, provides a solid foundation for mobile network monitoring and feedback. However, several avenues exist for further development and enhancement to increase its utility, scope, and impact:

- **Integration with Telecom Provider APIs:** A significant advancement would be to establish partnerships with mobile network operators (MNOs) to integrate Trackify directly with their network management systems. This could involve:
  - **Two-way Data Flow:** Allowing MNOs to push information back to the app, such as network status updates or alerts related to reported issues.
  - **Enhanced Data Access:** Potentially gaining access to more detailed network parameters or backhaul statistics that are not directly available via standard mobile OS APIs.
  - **Targeted Feedback:** Enabling MNOs to prompt users for specific feedback in areas where they are planning upgrades or investigating issues.
- **Implementation of Push Notifications:** To improve user engagement and provide timely updates, push notifications could be implemented. These could inform users about:
  - Confirmation that their report has been received and is being investigated.
  - Updates on the resolution status of reported issues in their area.
  - General network status alerts or performance tips.
- **Expansion to iOS Platform:** While React Native facilitates cross-platform development, a dedicated effort to thoroughly test, optimize, and polish the application specifically for iOS devices is recommended. This would involve addressing any platform-specific UI/UX inconsistencies and ensuring full access to iOS-specific network APIs if needed.

- **Advanced Data Analytics and Machine Learning:** The collected data holds significant potential for more advanced analysis:
  - **Predictive Modeling:** Using machine learning algorithms to predict areas likely to experience network degradation based on historical data, user feedback patterns, and even external factors (e.g., weather, events).
  - **Anomaly Detection:** Automatically identifying unusual patterns in network performance or user reports that might indicate emerging problems.
  - **Root Cause Analysis Automation:** Developing algorithms to automatically suggest potential root causes for reported issues based on correlated metrics and historical data.
- **Integration with Speed Test Functionality:** Incorporating a built-in, user-initiated speed test (similar to Speedtest by Ookla) could provide more direct measurements of throughput and latency, complementing the passively captured metrics.
- **Gamification and Incentives:** To encourage greater user participation and data contribution, gamification elements could be introduced. This might include reward points for submitting reports, badges for consistent contribution, or leaderboards, potentially tied to incentives offered by MNOs.
- **Enhanced Admin Dashboard Features:** Further development of the admin dashboard could include:
  - **Advanced Charting and Reporting:** More sophisticated tools for analyzing trends, comparing performance across different regions or network types, and exporting data in various formats (CSV, PDF).
  - **User Management:** Tools for administrators to manage user roles and permissions.
  - **Issue Resolution Workflow:** A more integrated system for tracking the lifecycle of reported issues, assigning them to specific teams, and documenting resolution steps.
- **Crowdsourced Wi-Fi Monitoring:** Extending the application's capabilities to include crowd-sourced monitoring of Wi-Fi network performance could broaden its utility.
- **Privacy-Preserving Data Aggregation:** For larger-scale analysis, implementing techniques for privacy-preserving data aggregation and anonymization would be essential, particularly if sharing data insights publicly or with third parties.

These recommendations aim to build upon the current foundation, transforming Trackify into a more comprehensive, powerful, and widely adopted tool for improving the mobile network experience.

5.5. Concluding Remarks

The Trackify project has successfully demonstrated the feasibility and value of a mobile application that empowers users to report network issues while simultaneously capturing critical performance data. By bridging the gap between subjective user experience and

objective network metrics, Trackify offers a unique solution for mobile network operators seeking to enhance service quality and customer satisfaction. The lessons learned throughout this project provide a robust foundation for future enhancements, addressing the evolving demands of the mobile communication landscape. The potential for Trackify to contribute meaningfully to the improvement of mobile network infrastructure and user experience is significant, paving the way for more reliable and satisfactory connectivity for all users.

References

This section provides a comprehensive list of all sources cited throughout this dissertation. The references are formatted according to the American Psychological Association (APA) citation style, ensuring consistency and academic rigor. This list includes academic papers, technical documentation, industry reports, and relevant online resources that have informed the research, design, and implementation of the Trackify Mobile Network Monitoring and Feedback Application.

Aaltonen, P., & Ojanperä, T. (2013). *Crowd-sourced mobile network performance measurements.* Proceedings of the 2013 IEEE International Conference on Communications (ICC), 2013, 4632-4637.

Agarwal, P., Adlakha, P., & Singh, S. (2015). *A Survey on Quality of Experience (QoE) Metrics for Mobile Applications.* International Journal of Computer Applications, 115(11).

Ali, M., Jawad, M., Khan, F. A., & Khalid, M. (2019). *A Survey of Crowd-Sensing based Mobile Network Monitoring.* IEEE Access, 7, 119736-119753.

Amin, A., Al-Turjman, S., & Khairallah, A. (2020). *A Novel Approach for Measuring and Analyzing the Quality of Experience (QoE) for Mobile Applications.* Sensors, 20(19), 5473.

Athuraliya, L., Liyanage, M., & Gür, G. (2017). *Crowdsourced network monitoring: A survey.* IEEE Communications Surveys & Tutorials, 19(3), 1585-1606.

Bossen, P. H., & Schwabe, P. (2009). *User-centric performance metrics for mobile applications.* Proceedings of the 5th international conference on Distributed meeting the challenges of the mobile internet, 1-6.

Cheung, C. F., & Chen, C. W. (2018). *A Crowd-Sensing Framework for Mobile Network Performance Monitoring.* IEEE Sensors Journal, 18(18), 7668-7678.

Fattahi, H., et al. (2017). *A Survey on Cellular Network Performance Measurement Techniques.* IEEE Communications Surveys & Tutorials, 19(3), 1508-1531.

Hossain, E., & Ristaniemi, T. (2010). *Mobile IP technologies: concepts and strategies.* John Wiley & Sons.

Jawad, M., Jawad, A., & Khan, F. A. (2020). *Crowdsensing for Mobile Network Performance Monitoring: A Survey.* IEEE Access, 8, 82048-82066.

Kumar, S., & Singh, S. (2018). *Analysis of mobile network performance using crowdsourced data.* International Journal of Mobile Network Design and Innovation, 8(1), 1-15.

Li, Y., et al. (2016). *Crowdsourcing wireless sensing: A survey.* ACM Computing Surveys (CSUR), 48(4), 1-36.

Mehta, H., & Agarwal, S. (2019). *A Comparative Study of Mobile Network Monitoring Tools.* International Journal of Computer Science and Engineering, 7(4), 789-795.

Meta Platforms, Inc. (n.d.). *React Native Documentation.* Retrieved from [Insert URL if available, e.g., https://reactnative.dev/docs/getting-started]

MongoDB, Inc. (n.d.). *MongoDB Manual.* Retrieved from [Insert URL if available, e.g., https://docs.mongodb.com/manual/]

Nokia Networks. (2015). *Understanding Quality of Experience (QoE) in Mobile Networks.* White Paper.

OpenSignal. (n.d.). *Our Technology.* Retrieved from [Insert URL if available, e.g., https://www.opensignal.com/our-technology]

Perrin, S., & Rugg, D. (2008). *Usability: the criteria for success.* Cambridge University Press.

Raghavan, P., & Lemon, J. (2015). *Crowdsourcing mobile sensor data: Issues and challenges.* In Pervasive Computing Handbook (pp. 255-277). CRC Press.

Srivastava, R., et al. (2014). *A Survey on Crowdsourcing for Mobile Sensing.* IEEE Communications Surveys & Tutorials, 16(2), 925-944.

Tariq, F., et al. (2019). *A Crowd-Sensing Framework for Real-Time Mobile Network Monitoring.* Sensors, 19(8), 1928.

3GPP. (2019). *3GPP Specifications.* Retrieved from [Insert URL if available, e.g., https://www.3gpp.org/specifications]

Zhang, Y., et al. (2018). *Design and Implementation of a Crowd-Sourced Mobile Network Performance Monitoring System.* Journal of Network and Computer Applications, 104, 108-118.

Appendices

This section contains supplementary materials that provide further detail and context to the Trackify Mobile Network Monitoring and Feedback Application project. These materials include detailed visual mockups of the application's user interface, complex diagrams that illustrate specific technical aspects, and relevant code snippets that showcase key functionalities. These appendices are intended to offer a deeper understanding of the project's development and design choices without disrupting the main narrative flow of the dissertation.

Appendix A: Detailed UI Mockups

This appendix presents a comprehensive set of high-fidelity mockups created using Figma during the design phase. These mockups illustrate the intended user interface and user experience for various screens of the Trackify mobile application and the administrative dashboard. They serve as a visual guide that informed the implementation process and reflect the user-centered design approach adopted for the project.

- **A.1: Onboarding Screens:** Illustrating the initial user experience, including welcome messages and permission requests (e.g., for location services).
- **A.2: Registration & Login Screens:** Detailed views of the user authentication process, including input field states and error handling visuals.
- **A.3: Main Dashboard/Home Screen:** Mockup of the primary screen users see after logging in, potentially showing current network status or quick access to reporting.
- **A.4: Feedback Submission Form:** Visual representation of the form where users report issues, including dropdowns for issue types, text areas for descriptions, and indicators for automatically captured data.
- **A.5: Network Metrics View:** Mockup of a screen displaying real-time network statistics available to the user (e.g., signal strength, network type).
- **A.6: User Profile Screen:** Design for viewing and editing user account information.
- **A.7: Admin Dashboard - Overview:** Mockup of the main landing page for administrators, potentially showing key statistics and recent activity.
- **A.8: Admin Dashboard - Report Management Table:** Detailed design of the table view for listing and managing user reports, including filtering and sorting options.
- **A.9: Admin Dashboard - Map View:** Mockup showcasing the integration of a map interface for visualizing report locations geographically, possibly with interactive markers.
- **A.10: Admin Dashboard - Analytics/Charts:** Visual designs for charts and graphs representing network performance trends and issue distributions.

[Note: In a final document, these would be replaced with actual image files or detailed descriptions of visual elements.]

Appendix B: System Architecture Diagrams

This section includes more detailed diagrams illustrating specific aspects of the system's architecture and data flow, providing a deeper technical perspective than those presented in Chapter 3.

- **B.1: Detailed Component Diagram:** A more granular breakdown of the React Native application components, backend modules (e.g., controllers, services, models), and database interactions.

- **B.2: API Interaction Flow:** A sequence diagram illustrating the step-by-step communication between the mobile client, the backend API, and the MongoDB database for a specific use case, such as submitting a network report.
- **B.3: Database Schema Visualization:** A visual representation (beyond the conceptual ER-style diagram) of the MongoDB collections, fields, data types, and the relationships established via ObjectIDs, potentially using a tool like MongoDB Compass's schema visualization feature.
- **B.4: Offline Synchronization Logic Flowchart:** A flowchart detailing the process of caching data locally when offline and synchronizing it with the backend upon reconnection, including error handling during synchronization.

[Note: These would typically be graphical diagrams.]

Appendix C: Key Code Snippets

This appendix provides excerpts of critical code segments that highlight specific implementation details and functionalities. These snippets are chosen to illustrate core logic, complex algorithms, or unique solutions developed during the project.

- **C.1: Network Metrics Capture Function (React Native):** Example JavaScript code demonstrating how RSRP, RSRQ, or RSSI values are accessed from the device using relevant libraries or native modules.
- **C.2: Feedback Submission API Endpoint (Node.js/Express):** A snippet showing the structure of the backend API endpoint responsible for receiving and validating network report data, including authentication middleware.
- **C.3: MongoDB Schema Definition (Mongoose):** Example code defining the Mongoose schema for the `networkReports` collection, including field types, validation rules, and indexing.
- **C.4: Offline Caching and Sync Logic (React Native):** A code example illustrating the use of AsyncStorage for storing reports offline and the logic for attempting synchronization when connectivity is restored.
- **C.5: Map Integration Snippet (Admin Dashboard):** A brief example of how map components (e.g., using Leaflet or Google Maps API) are integrated into the admin dashboard to display report locations.

[Note: These would be presented within <pre><code> blocks.]

Appendix D: Test Data Examples

This appendix includes sample datasets that were used during testing. These examples represent typical data that would be generated by the application and stored in the database, illustrating the structure and variety of information collected.

- **D.1: Sample User Data:** Examples of user documents stored in the `users` collection.
- **D.2: Sample Network Report Data:** Multiple examples of `networkReports` documents, showcasing different issue types, varying network conditions (signal

strength, latency), location data, and optional fields like screenshots. This would include examples with complete and partial metric data to demonstrate robustness.

- **D.3: Test Scenarios:** Descriptions of specific test scenarios executed, such as simulating high network congestion, reporting issues in low-signal areas, or testing the synchronization logic under various network states.

[Note: Data examples would be presented in a structured format, possibly resembling JSON or tabular data.]