GeoEdu Insight Journal: Geography and Education Geography
Vol. 1, No. 3, October 2026, pp. 179~193
ISSN: 3163-9070, DOI: 10.37251/gedij.v1i2.3984

Development of an Android-Based Location-Based Service Application for Base Transceiver Station Mapping and Shortest-Route Determination Using the Floyd–Warshall Algorithm

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Article Info

Article history:

Received Jul 3, 2026
Revised Aug 7, 2026
Accepted Oct 25, 2026
Online First Oct 31, 2026

Keywords:

Android Application
Base Transceiver Station
Floyd–Warshall Algorithm
Location-Based Services
Shortest Path Algorithm

ABSTRACT

Purpose of the study: This study aims to develop an Android-based Location-Based Service application to map CV.2K base transceiver station locations in Pekanbaru and assist field technicians in identifying base transceiver station locations and determining the shortest routes using the Floyd–Warshall algorithm.

Methodology: The application was developed using the Rational Unified Process (RUP) methodology. The system was implemented on the Android platform using Java, with PHP as the server-side connector and MySQL as the database management system. Google Maps and GPS were integrated to support location mapping and positioning. The Floyd–Warshall algorithm was applied for shortest-path computation, while functional testing employed the Black Box method.

Main Findings: The application successfully displayed base transceiver station locations, maintenance status, and route guidance on Android devices. The shortest-route results generated by the application were consistent with manual calculations across all ten test cases, achieving an agreement rate of 100%. The application also demonstrated the integration of location information and route computation to support technicians in accessing base transceiver station locations in the tested area.

Novelty/Originality of this study: The originality of this study lies in the integration of Android-based Location-Based Services, base transceiver station maintenance information, and the Floyd–Warshall algorithm into a single application designed for CV.2K field technicians. This domain-specific implementation provides a mobile-based approach to accessing base transceiver station location data and shortest-route guidance within the operational context of a telecommunications service provider.

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1. INTRODUCTION

Telecommunication infrastructure is a vital component in supporting digital connectivity and providing internet services to the public. The presence of base transceiver station enables the distribution of communication signals across a telecommunication network, reaching various geographical areas [1]-[3]. Managing such infrastructure requires periodic monitoring and maintenance to ensure the consistent quality of network services [4]-[6]. The distribution of base transceiver station units across diverse geographical locations creates a need for spatial information that can assist technicians in accurately identifying the locations of this infrastructure. In this context, the integration of Geographic Information Systems (GIS), the Global Positioning System (GPS), and Location-Based Services facilitates the management of location data and navigation to telecommunication infrastructure [7], [8].

As an internet service provider, CV.2K operates a number of base transceiver station units spread across several districts in Pekanbaru City. This geographical distribution necessitates that technicians have access to information regarding base transceiver station locations and can determine optimal travel routes when conducting inspections and maintenance. Limited access to integrated location data can hinder the process of identifying destinations and planning routes for technicians [9]-[11]. Furthermore, there is a need to provide information on distances and travel directions based on the user's current geographical position. Consequently, a location-based system is required one that integrates data on base transceiver station units and technicians, while incorporating a mechanism to calculate the shortest route, all within a single application.

Utilizing Location-Based Services offers an effective approach to integrating geographical data with the navigation needs of mobile device users [12]-[14]. This technology allows a user's position to be identified via GPS and linked to specific locations stored within a geographical database [15]-[17]. To determine travel routes, the Floyd Warshall algorithm can be employed to calculate the shortest path between nodes in a weighted graph representation of the network [18]-[20]. By integrating these approaches, an application can display base transceiver station locations, distance information, and the optimal route to a target destination. This research implements such an approach through a client-server-based Android application, developed using the Java programming language, to support the operational needs of CV.2K technicians in Pekanbaru City.

Research on route finding and planning indicates that path optimization is a critical issue in spatial data management and the development of location-based services [21], [22]. Zhang et al. [23] have identified the evolution of route recommendation methods ranging from classical algorithms to modern approaches along with the challenges of implementing them in urban environments. Other studies emphasize that mobile navigation systems must account for the interplay between user characteristics, spatial representation, and the presentation of navigational information [24]-[26]. Huang et al. [12] discuss the challenges of context modeling and information processing within location-based services, highlighting the importance of integrating location data with service requirements. Meanwhile, Sakti et al. [27] developed a geospatial intelligence framework to support the planning of base transceiver station infrastructure in Indonesia, based on location suitability and internet access needs.

Existing research on route optimization, mobile navigation, and geospatial analysis has evolved through various methodological approaches and application contexts. However, studies focused on urban route recommendations, user-centric spatial navigation, and location-based services context modeling differ from the operational requirements involved in base transceiver station maintenance. Furthermore, the work of Sakti et al. [27] centers primarily on location suitability and the prioritization of base transceiver station infrastructure development, rather than on the navigation of technicians to existing base transceiver station sites. Consequently, there is a research gap regarding the integration of base transceiver station location data, technician positioning, and shortest-path routing within a unified mobile navigation system designed to support telecommunications infrastructure maintenance. This specific need serves as the foundation for the development of the "CV.2K base transceiver station location-based services " application in Pekanbaru City.

The novelty of this research lies in the integration of Location-Based Services with the Floyd–Warshall algorithm, applied to the context of operational navigation toward the base transceiver station sites of an internet service provider. Unlike research focused on infrastructure site planning, this approach utilizes geographic information to assist technicians in identifying base transceiver stations and determining travel routes. The system integrates a database of base transceiver station locations, user positioning via GPS, map visualization, and data regarding distances and routes to destinations. This is implemented through a client-server Android application that provides technicians with base transceiver station information and navigation tools. Consequently, the contribution of this research lies in the integration of technology and its application within the operational context of telecommunications infrastructure maintenance, rather than in the development of the well-established Floyd–Warshall algorithm.

Developing a location-based navigation system for telecommunications infrastructure is essential for facilitating access to geographic information during the operation and maintenance of base transceiver station sites. This need becomes particularly significant when technicians must locate infrastructure distributed across various geographic areas. Therefore, this research aims to develop a Location-Based Services application for mapping CV.2K's base transceiver station sites in Pekanbaru City by applying the Floyd–Warshall algorithm. The

application is designed to display base transceiver station locations, determine the user's position, calculate the shortest route, and provide information on the distance to the destination. The functional performance of the application is evaluated through Black Box testing and shortest-path verification to ensure that the implementation aligns with the system's requirements.

2. RESEARCH METHOD

2.1. Research Design

This study employed a software development research approach to design and implement a Location-Based Services application for mapping Base Transceiver Station locations and determining the shortest routes to support maintenance activities at CV.2K in Pekanbaru, Indonesia. The development process adopted the Rational Unified Process, which provides a structured framework for software development through four iterative phases: inception, elaboration, construction, and transition [28], [29].

The inception phase focused on identifying operational problems, determining system requirements, and defining the proposed application. The elaboration phase involved analysing system requirements and designing the database, system components, and application interfaces. The construction phase involved implementing the application using Java on the Android platform and integrating it with the server-side database. Finally, the transition phase involved testing the developed application to evaluate the functionality of its principal features.

Table 1. Research activities based on the Rational Unified Process (RUP)

Development phase	Main activities	Research output
Inception	Problem identification, literature review, requirement identification, and system proposal preparation	System requirements and development objectives
Elaboration	System analysis, database design, architecture design, and interface design	System and database design
Construction	Application coding, database integration, and implementation of application features	Functional Android-based location-based services application
Transition	Functional testing and application evaluation	Testing documentation and evaluation results

2.2. Research Context and System Requirements

The research was conducted in the operational environment of CV.2K, an internet service provider operating in Pekanbaru, Indonesia. The company manages base transceiver station infrastructure distributed across different geographical locations. The distribution of these facilities creates operational requirements for technicians to identify base transceiver station locations and obtain route information when conducting maintenance activities [30], [31].

The application was designed to support technicians through several principal functions, including displaying base transceiver station locations, providing base transceiver station information, identifying facilities requiring maintenance, obtaining the user's geographic position through GPS, displaying route information to selected base transceiver station destinations, and updating base transceiver station maintenance status. The system was developed as an Android-based mobile application connected to a server through an internet connection. Its functional scope covered base transceiver station location identification, geographic visualization, shortest-route calculation, and maintenance-status management.

2.3. Geographic Data and Road-Network Modelling

The application integrated three main types of information: base transceiver station location data, user positioning data, and road-network data. base transceiver station coordinates were obtained manually using an Android device. The digital map was sourced from Google Maps, while road-network information was prepared for the application and stored in the server database. The road-network data were represented as a directed weighted graph. In this representation, road intersections or connection points functioned as vertices, while road segments represented edges. Each edge contained a distance value used as the weight in the shortest-route calculation. The road data used in the implementation were described in the original thesis as simulated field data derived from Google Maps and adjusted to the application's requirements. Consequently, these data should not be described as a comprehensive, independently verified field survey of all roads in Pekanbaru.

Table 2. Attributes of the road-coordinate database

No.	Database attribute	Description
1	No	Road-coordinate record identifier
2	nama_jalan	Road name
3	titik_awal	Initial vertex of the directed graph
4	titik_akhir	Terminal vertex of the directed graph
5	x1	Longitude of the initial vertex
6	y1	Latitude of the initial vertex
7	x2	Longitude of the terminal vertex
8	y2	Latitude of the terminal vertex
9	panjang	Distance between the initial and terminal vertices
10	keterangan	Description of the terminal point, such as a road or intersection
11	kategori	Category of the road or point

The geographic information was used to identify the user's starting position and the selected base transceiver station destination. The road-network graph provided the connectivity and distance information required by the Floyd–Warshall algorithm.

2.4. System Architecture and Data Management

The application adopted a client-server architecture consisting of an Android mobile application, a PHP-based communication component, and a MySQL database server. The Android application functioned as the client interface through which technicians accessed base transceiver station information and navigation features. The PHP component facilitated communication between the mobile application and the server database. MySQL stored base transceiver station information, geographic coordinates, road-network attributes, and maintenance-status records. The system also supported administrative activities for managing base transceiver station and road-coordinate information. The system also included database administration functions.

The administrator could update base transceiver station location coordinates, road coordinates, and base transceiver station status. Technicians used the mobile application to access base transceiver station information, identify maintenance destinations, and obtain route guidance. The main system components and their functions are summarized in Table 3.

Table 3. System components and their functions

Component	Technology	Function
Mobile client	Android	Provides the technician interface
Application programming	Java	Implements application functionality
Positioning component	GPS	Obtains the user's geographic coordinates
Mapping service	Google Maps	Provides geographic map visualization
Communication component	PHP	Facilitates client-server communication
Database server	MySQL	Stores base transceiver station, road-coordinate, and status data
Server environment	WAMP	Supports server-side application services

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2.5. Development Tools and Implementation Environment

The application was developed using Java for the Android platform. PHP was used for server-side communication, and MySQL was used as the database management system. The application was implemented and tested using the hardware and software environment documented in the original thesis. Because the research was conducted in 2025, the specifications are presented as the historical development environment of the study rather than as current technology recommendations.

Table 4. Hardware and software specifications

Component	Specification
Mobile device	Sony Xperia Mini Pro
Operating system	Android 4.0.4 Ice Cream Sandwich
Processor	1 GHz
RAM	512 MB
External storage	8 GB
Internal storage	400 MB
Programming language	Java
Development environment	Eclipse Galileo 3.5
Java development kit	JDK 6u24
Android development tools	Android SDK and ADT 8.0

Component	Specification
Server-side programming	PHP
Database	MySQL
Database administration	phpMyAdmin (WAMP)
Digital map	Google Maps
Positioning technology	GPS

2.6. Shortest-Route Calculation Using the Floyd–Warshall Algorithm

The shortest-route calculation was implemented using the Floyd–Warshall algorithm. The road network was represented as a directed weighted graph, in which vertices represented road connection points and edges represented road segments. The distance of each road segment was assigned as its corresponding edge weight.The algorithm calculated the shortest distances between pairs of vertices by iteratively considering intermediate vertices. Initially, the distance matrix was populated using the available road-segment distances. A zero value was assigned to the distance from a vertex to itself, while the absence of a direct connection was represented by infinity.

The distance matrix was subsequently updated using the following equation:

$$D_{ij}^{(k)} = \min\left(D_{ij}^{(k-1)}, D_{ik}^{(k-1)} + D_{kj}^{(k-1)}\right) \quad \ldots (1)$$

where:

- $D_{ij}^{(k)}$ represents the shortest distance from vertex i to vertex j after considering vertex k as an intermediate vertex.
- $D_{ij}^{(k-1)}$ represents the previously calculated distance between vertices i and j.
- $D_{ik}^{(k-1)}$ represents the distance from vertex i to vertex k.
- $D_{kj}^{(k-1)}$ represents the distance from vertex k to vertex j.
- k represents the intermediate vertex considered during the iteration.

2.7. System Testing and Evaluation

System testing was conducted during the transition phase of the RUP development process. The evaluation focused on the functional operation of the application using the Black Box testing method. This approach examined whether the application produced the expected output in response to user actions without evaluating its internal source-code structure. The testing scenarios covered the main functions of the application, including base transceiver station listing, destination selection, maintenance information, route navigation, application information, and base transceiver station status updates. Application access was also tested at different locations and with different network providers.

Table 5. Black Box functional testing scenarios

No.	Test scenario	Expected output
1	Open the base transceiver station List menu	The base transceiver station list is displayed
2	Select a base transceiver station destination	Destination information and route are displayed when GPS coordinates are available
3	Open the Maintenance menu	The list of base transceiver station requiring maintenance is displayed
4	Select a base transceiver station from the maintenance list	The selected base transceiver station location and information are displayed
5	Select the MAP function	The route to the selected base transceiver station is displayed when GPS coordinates are available
6	Open the About menu	Application information is displayed
7	Update base transceiver station status	The updated base transceiver station status is displayed

2.8. Methodological Limitations

The methodological scope of this study was limited to the development and functional testing of an Android-based location-based services application for base transceiver station mapping and shortest-route navigation. The road-network data used in the implementation were simulated field data derived from Google Maps, while base transceiver station coordinates were collected manually using an Android device [32], [33]. The study did not include a comprehensive evaluation of user satisfaction, usability, GPS positional accuracy, or comparative algorithm performance [34]. It also did not quantify the effect of the application on maintenance efficiency or technician productivity. Data security was identified as outside the scope of the original application

development. Therefore, the findings should be interpreted as evidence of the application's implemented functions rather than as evidence of measured improvements in operational performance.

3. RESULTS AND DISCUSSION

3.1. System Deployment and Database Implementation

The application was deployed through an Android client connected to a server over the internet. The Android device used GPS to obtain the technician's current coordinates, while the server provided base transceiver station and road-network data through a PHP-based connector. The original deployment design is presented in Figure 1.



Figure 1. Deployment architecture of the location-based services base transceiver station application.

The database design is shown in Figure 2. This study identifies three relevant database structures: a road coordinates table, a maintenance table, and an accounts table. The road coordinates table stores road segment identifiers, road names, start and end nodes within the graph, geographic coordinates, segment lengths, and related descriptions. The maintenance table stores base transceiver station names, status descriptions, and image references. The accounts table facilitates access to the database administration interface.

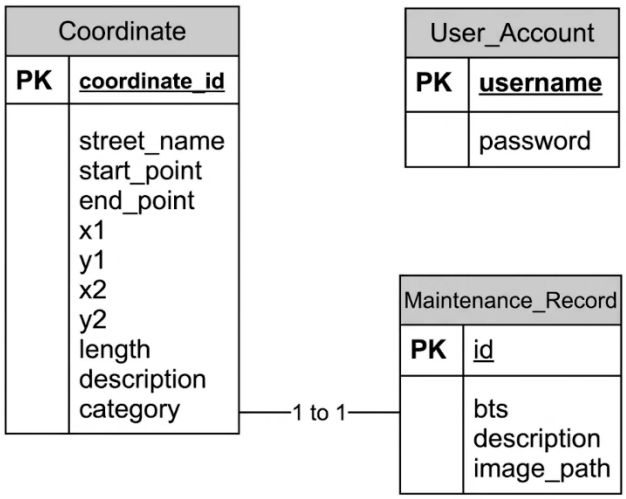


Figure 2. Logical database model for the location-based services base transceiver station application

This database structure links the geographic representation of road segments with base transceiver station -related operational information. Consequently, the application does not merely display base transceiver station points on a map; it also provides a data structure for representing road connectivity and storing maintenance status. However, the thesis does not report a formal evaluation of database integrity, transaction performance, or data synchronization under concurrent access

3.2. Weighted Road-Network Representation

The shortest-route computation was based on a weighted graph representing road connectivity in Pekanbaru. In this graph, nodes represent road intersections or locations, while edges represent road segments. Each edge is assigned a distance weight, allowing alternative paths between an origin and a destination to be compared.



Figure 3. Weighted road-network graph and manual route-computation example from base transceiver station Hotel Ibis to base transceiver station Xnet.

Four alternative routes were identified in the manual calculation. Their total distances are summarized in Table 6.

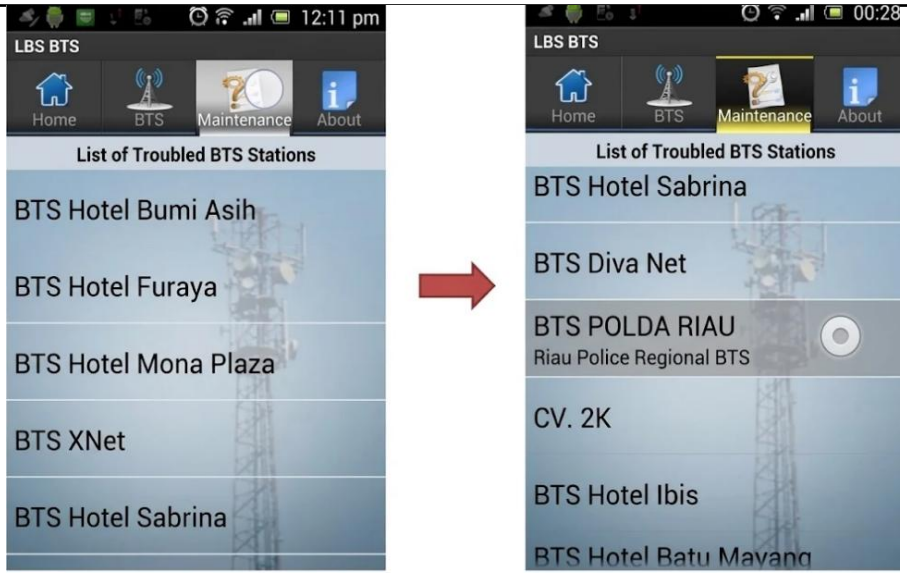
Table 6. Alternative route calculation from base transceiver station Hotel Ibis to base transceiver station Xnet

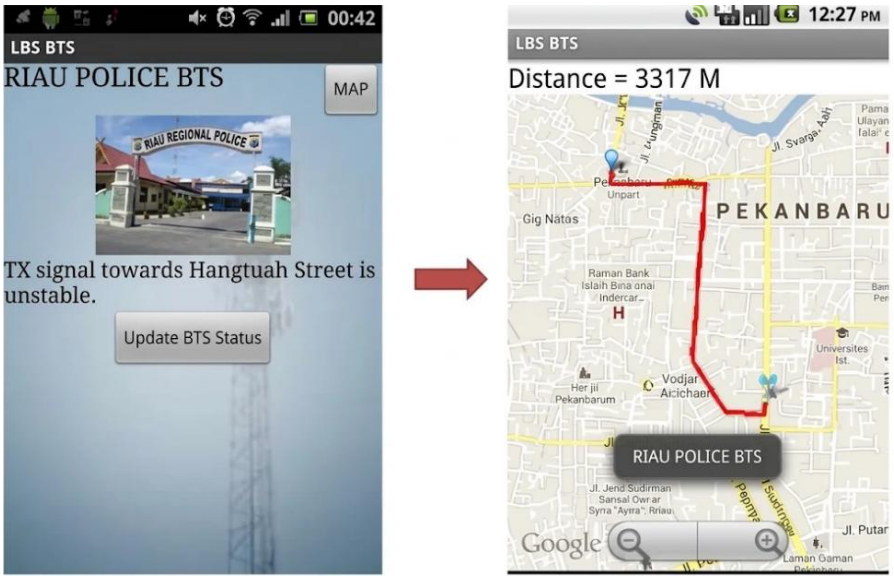
Route	Node sequence	Total distance (m)
I	a–b–s–r–j–o	7,042
II	a–b–c–k–l–m–n–o	8,150
III	a–b–s–q–p–h–i–j–o	7,482
IV	a–b–c–d–e–f–g–h–i–j–o	7,032

Route IV produced the lowest total distance, at 7,032 m. It was 10 m shorter than Route I, the second-shortest alternative, and 1,118 m shorter than Route II. The result indicates that the selected route was determined by comparing cumulative road-segment weights rather than simply choosing the route with the fewest intermediate nodes.

The application's route output was reported to match the manual calculation. This agreement provides an internal consistency check for the implementation in the tested example. Nevertheless, it should not be interpreted as an independent validation of the underlying road-network data, because the manual calculation and the application rely on the same modeled network and distance information.

Figure 4 presents selected original application screenshots. The screenshots show the maintenance list, base transceiver station information, route display, and base transceiver station status-update interface.


12:11 pm
LBS BTS
Home
BTS
Maintenance
About
List of Troubled BTS Stations
BTS Hotel Bumi Asih
BTS Hotel Furaya
BTS Hotel Mona Plaza
BTS XNet
BTS Hotel Sabrina
00:28
LBS BTS
Home
BTS
Maintenance
About
List of Troubled BTS Stations
BTS Hotel Sabrina
BTS Diva Net
BTS POLDA RIAU
Riau Police Regional BTS
CV. 2K
BTS Hotel Ibis
BTS Hotel Batu Mayang


00:42
LBS BTS
RIAU POLICE BTS
MAP
RIAU REGIONAL POLICE
TX signal towards Hangtuah Street is unstable.
Update BTS Status
12:27 PM
LBS BTS
Distance = 3317 M
PEKANBARU
RIAU POLICE BTS
Google

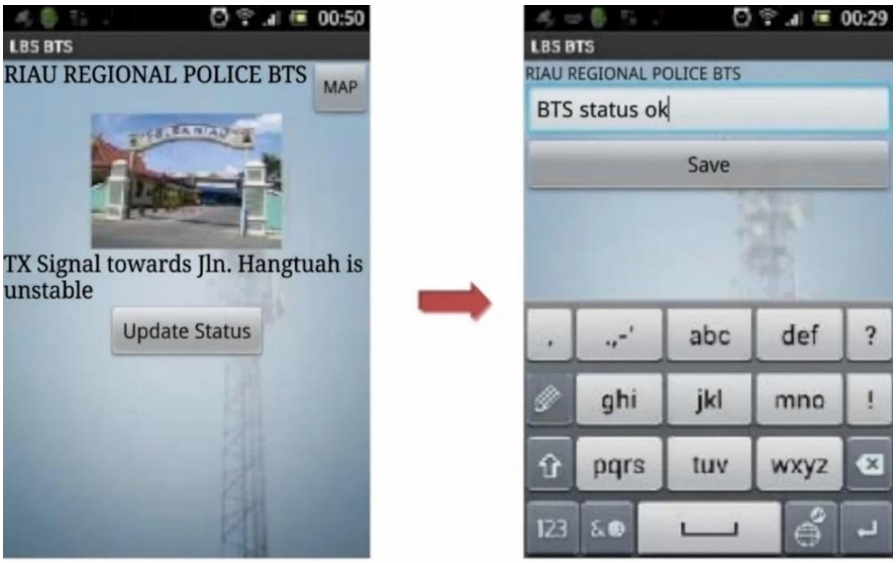

00:50
LBS BTS
RIAU REGIONAL POLICE BTS
MAP
TX Signal towards Jln. Hangtuah is unstable
Update Status
00:29
LBS BTS
RIAU REGIONAL POLICE BTS
BTS status ok
Save



Figure 4. Android application interface showing the base transceiver station maintenance list, base transceiver station information, route display, and status-update function.

The implementation scenario described in the thesis involved a technician located on Jalan Yos Sudarso who intended to visit base transceiver station Polda Riau. After selecting the relevant base transceiver station and activating the map function, the application displayed the route and the estimated route distance. The maintenance interface also allowed the technician to update the base transceiver station status after completing the maintenance activity.

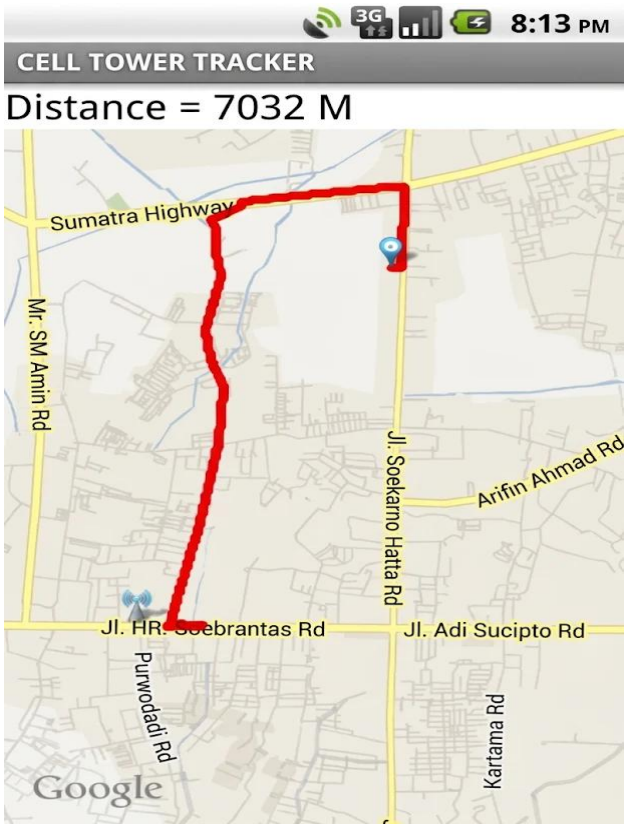


Figure 5. shows the route output for the Hotel Ibis– base transceiver station Xnet example. The application displayed a route distance of 7,032 m, corresponding to the result of the manual Floyd–Warshall calculation.

A further comparison was conducted for the route from Jalan Bakti to Hotel Ibis. Google Directions reported a route distance of 1,800 m, while the proposed location-based services base transceiver station application calculated a distance of 1,881 m. This discrepancy was attributed in the thesis to differences in the road-network representations used by Google Maps and the application, particularly regarding the configuration and direction of traffic on Jalan Soekarno Hatta and the turning movements involving Jalan Dirgantara. In the application's road-network database, these road segments were represented in a way that resulted in a different route, including a U-turn on Jalan Dirgantara. This finding highlights the importance of accurate and consistent road-network data in determining shortest-path results. However, the distance difference should not be interpreted as evidence that either system provides a more accurate route, since no independent ground-truth measurement was reported to validate the actual route distance.

3.4. Functional Testing Results

Functional testing was conducted using the black-box method on a Sony Xperia Mini Pro smartphone. The test material consisted of coordinate data entered into the server database. The original test table reports successful results for the Home menu, base transceiver station menu, base transceiver station selection, Maintenance menu, selection of a maintenance base transceiver station, the MAP button, the About menu, and the base transceiver station status-update function.

For journal presentation, the original results are reorganized in Table 7. The original test numbering is retained where it was reported.

Table 7. Functional testing results of the location-based services base transceiver station application

No.	Tested component	Observed output	Result
1	Home menu	Application opened and base transceiver station locations were displayed	Pass
2	base transceiver station menu	base transceiver station list was displayed	Pass
3	Select one base transceiver station	User coordinates were obtained and the route, base transceiver station name, and distance were displayed when GPS coordinates were available	Pass
4	Maintenance menu	List of base transceiver station locations requiring maintenance was displayed	Pass
5	Select a maintenance base transceiver station	base transceiver station location image and information were displayed	Pass
6	MAP button	Route and distance to the selected base transceiver station were displayed when GPS coordinates were available	Pass
9	About menu	Application information was displayed	Pass
10	Update status button	Updated base transceiver station status was displayed after submission	Pass

All eight functional testing components were reported as successful. This indicates that the application's core functions operate in accordance with the expected outputs defined in the reported test scenarios. These results should be understood as evidence that the application's features are functioning correctly, rather than as a comprehensive benchmark for aspects such as usability, GPS accuracy, system reliability, or performance under heavy server load.

3.5. Shortest-Route Validation Across Multiple Locations

In addition to the Hotel Ibis–Xnet example, the thesis reports route tests for ten origin–destination pairs. For each pair, several alternative routes were manually compared with the route returned by the application. The selected system distance matched the shortest distance reported from the manual calculation in all ten cases.

Table 8. Comparison of manual and system shortest-route results

No.	Origin	Destination	Shortest manual distance (m)	System result (m)	Agreement
1	UIN SUSKA	base transceiver station Hotel Ibis	9,733	9,733	Yes
2	UIN SUSKA	base transceiver station H. Ratu Mayang Garden	12,580	12,580	Yes
3	base transceiver station Hotel Ibis	base transceiver station Xnet	7,032	7,032	Yes

4	base transceiver station Hotel Ibis	base transceiver station H. Ratu Mayang Garden	8,607	8,607	Yes
5	CV.2K	base transceiver station DivaNet	3,764	3,764	Yes
6	CV.2K	base transceiver station NeoNet	8,566	8,566	Yes
7	base transceiver station Hotel Ibis	base transceiver station PrimaNet	10,037	10,037	Yes
8	base transceiver station DivaNet	base transceiver station Hotel Sabrina	3,009	3,009	Yes
9	UIN SUSKA	base transceiver station Hotel Sabrina	13,000	13,000	Yes
10	CV.2K	base transceiver station Xnet	12,554	12,554	Yes

The application produced the same shortest-distance results as the manual calculations in all ten test cases, yielding an agreement rate of 100% (10 out of 10 cases). This result provides evidence of the consistency of the implemented route-selection algorithm with the manual calculations for the tested road network. Nevertheless, the findings should be interpreted within the scope of the evaluation. The ten test cases do not represent a large-scale benchmark, and the agreement between the application and manual calculations does not independently verify the completeness or accuracy of the underlying road-network data, including road segments, travel directions, and distance measurements across Pekanbaru.

The findings demonstrate the feasibility of integrating a mobile Location-Based Service with a graph-based shortest-path algorithm to support base transceiver station maintenance activities. The developed application combines three main functions: determining the technician's location using GPS, retrieving base transceiver station and road-network information from a server, and displaying route information and the corresponding distance on a mobile map. The consistency between manual calculations and system-generated results provides evidence of the correctness of the implemented route-selection procedure within the tested road network. In the Hotel Ibis–Xnet case, the algorithm selected Route IV, with a distance of 7,032 m, as the shortest of the four alternatives. The application produced the same result. Furthermore, all ten additional origin–destination test cases showed agreement between the manual and system calculations, indicating that the application consistently identified the minimum-distance routes within the evaluated test set.

Nevertheless, these findings should be interpreted within the scope of the evaluation. Although the study demonstrates the functional operation of the application and the consistency of its route calculations, it does not establish the real-world optimality of the generated routes under changing traffic conditions. The edge weights represent road distances, while the evaluation does not incorporate real-time congestion, travel time, road closures, or other dynamic routing conditions. Moreover, the agreement between manual and system calculations represents an internal consistency assessment rather than independent validation, since both calculations rely on the same underlying road-network representation. Therefore, the primary contribution demonstrated by this study is the integration and implementation of location-based services -based base transceiver station mapping and distance-based route selection, rather than evidence of superior navigation accuracy or travel-time optimization.

The findings are consistent with previous research that describes Location-Based Services as an integration of mobile positioning, communication networks, geographic information systems, and spatial information. Sadoun and Al-Bayari [35] discussed the application of GIS in location-based services and highlighted the role of positioning technologies in supporting location-aware services. Similarly, Raper et al. [36] reviewed the technical and application-related challenges of location-based services, including positioning technologies, geographic information, mobile interfaces, and service delivery. Building on these principles, the present study applies location-based services technology to a specific operational context: supporting technicians in locating and maintaining geographically distributed base transceiver station infrastructure. Unlike general-purpose location services, the proposed application connects the user's position with infrastructure-specific information, including base transceiver station locations and maintenance status.

The route-selection component can also be considered in relation to previous studies on shortest-path algorithms for transportation networks. Van Vliet [37] examined shortest-path algorithms for transport networks and discussed the relationship between computational efficiency and network characteristics. Zeng and Church [38] investigated shortest-path computation on real road networks and highlighted the use of A for efficient route searching. These studies emphasize the distinction between identifying a minimum-distance path and selecting an algorithm that performs efficiently for a particular network structure. The present study demonstrates that Floyd–Warshall can consistently produce the expected shortest-distance results for the tested base transceiver station routes. However, because the algorithm calculates shortest paths between all pairs of vertices and has a time complexity of (O(V^3)), its computational suitability for larger or frequently updated road networks requires further evaluation.

Recent studies have further highlighted the importance of location data and road-network quality in routing applications. Xu et al. [39] examined vehicular routing behavior using location-based services data and discussed challenges associated with location-sampling rates and the reconstruction of actual routes. Badran et al. [40] reviewed methods for extracting road-network features from GPS data and identified limitations related to sampling bias and the completeness of reconstructed road representations. These issues are relevant to the present study because the generated routes depend on the road-segment coordinates, network connectivity, and distance information stored in the application database. The observed difference between Google Directions and the proposed application for the Jalan Bakti–Hotel Ibis route further illustrates how differences in road-network representation can lead to different route distances and turning movements.

Furthermore, Li et al. [21] surveyed route-search and planning methods in spatial data management and location-based services, demonstrating that route planning encompasses different query types, network structures, and optimization objectives. In comparison with these broader studies, the present research addresses a more specific operational problem: providing distance-based navigation to company-owned base transceiver station locations. Accordingly, its contribution is best understood as a domain-specific implementation of location-based services based route planning for telecommunications infrastructure maintenance, rather than a general advancement in shortest-path algorithms.

The main contribution of this study lies in the integration of mobile location-based services, base transceiver station maintenance information, and Floyd–Warshall-based route computation within a single Android client–server application. Unlike general-purpose navigation applications, the proposed system is designed to address the operational needs of CV.2K technicians by combining base transceiver station location visualization, maintenance-status information, and route-distance guidance. The application also connects its mobile interface to a server-side database containing road-coordinate and base transceiver station maintenance information, enabling users to access geographic and operational data through the same platform.

The comparison between manual calculations and system-generated results across ten origin–destination pairs provides evidence of the consistency of the implemented route-selection process within the tested network. Thus, the study's contribution is primarily practical and application-oriented: it demonstrates how established location-based services technologies and a classical shortest-path algorithm can be integrated to support a specific infrastructure-maintenance workflow. The novelty should therefore be understood as a domain-specific system integration and implementation, rather than the development of a new shortest-path algorithm or a new theoretical model of location-based services.

The findings have practical implications for field-maintenance activities in organizations managing geographically distributed telecommunications infrastructure. First, the application can assist technicians in identifying base transceiver station locations and obtaining route-distance information without having to search for each location manually. Second, integrating base transceiver station maintenance-status information with map-based navigation enables technicians to access asset locations and reported conditions through a single mobile interface. This functionality may support the planning and prioritization of maintenance visits, although its effect on maintenance efficiency and technician productivity has not yet been quantitatively evaluated.

From a technical perspective, the results indicate that the reliability of route selection depends on the quality of the road-network database, the availability of accurate GPS coordinates, and internet connectivity. The server-based data structure also provides a foundation for updating road-coordinate and base transceiver station maintenance information as operational conditions change. Consequently, practical deployment should prioritize road-network verification, regular database updates, reliable GPS positioning, and stable network access. The proposed approach may also inform the development of similar infrastructure-maintenance applications, provided that the asset locations, road-network data, and operational requirements are adapted to the target organization.

The proposed approach may be applicable to organizations that manage geographically distributed infrastructure assets and require mobile access to asset locations, maintenance status, and distance-based route information. Potential application areas include telecommunications facilities, utility infrastructure, and other geographically dispersed maintenance sites. However, the generalizability of the findings should be considered cautiously because the evaluation was conducted using CV.2K's base transceiver station locations and a specific road-network database in Pekanbaru. The results do not establish whether the same level of route consistency would be achieved in other cities or under different road-network conditions.

Several limitations should be acknowledged. First, the thesis reports that road and base transceiver station coordinates were collected or updated manually and identifies limitations concerning the completeness of available map data and the accuracy of coordinate points. Second, the route-selection process uses distance-based edge weights and does not account for real-time traffic conditions, travel time, road restrictions, or temporary road closures. Third, the evaluation focuses on black-box functional testing and agreement between manual and system route calculations. It does not provide a systematic assessment of GPS positional error, application usability, technician productivity, or computational performance across different network sizes. Fourth, the thesis identifies practical constraints involving GPS acquisition, weather conditions, physical obstructions, mobile-network quality, and occasional application instability when loading base transceiver station images. The reported access

time of approximately eight minutes under favorable conditions also indicates the need for further investigation of operational responsiveness.

Future research should address these limitations by expanding and independently verifying the road-network database, evaluating GPS positioning accuracy against surveyed reference coordinates, and comparing the performance of Floyd–Warshall with alternative shortest-path algorithms, particularly Dijkstra and A*. Such comparisons should consider different network sizes, computational times, and route-query workloads. In addition, incorporating travel-time weights, real-time traffic information, and road restrictions could improve the application's relevance to dynamic field-maintenance operations. These developments would provide a stronger basis for evaluating the system's scalability, reliability, and applicability beyond the CV.2K case study.

4. CONCLUSION

This study successfully developed an Android-based client–server Location-Based Service application for mapping CV.2K Base Transceiver Stations in Pekanbaru and providing technicians with location information and shortest-route guidance using the Floyd–Warshall algorithm. The application was able to retrieve base transceiver station information from the server, display base transceiver station locations and maintenance status on a digital map, and generate shortest-distance routes, with all ten tested route cases showing agreement between the system results and manual calculations. These findings demonstrate the practical potential of integrating location-based services technology and shortest-path computation to facilitate access to base transceiver station location and maintenance information in field operations. The application also provides a unified mobile platform through which technicians can view base transceiver station conditions and obtain route guidance, thereby supporting the organization of maintenance activities. Future research should improve the completeness of the road-network database by incorporating all relevant road types and traffic regulations, as well as validate road and base transceiver station coordinates through independent measurements. Further studies should also evaluate the application's computational performance, GPS positioning reliability, and usability under different network and environmental conditions, while exploring the integration of dynamic traffic and travel-time information.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the guidance and valuable contributions of the academic supervisor, examination committee, and academic coordinator throughout this research. The author also expresses sincere appreciation to the family, colleagues, and friends for their continuous support and encouragement.

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