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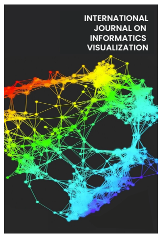

Smartphone-based Indoor Navigation for Guidance in Finding Location Buildings Using Measured WiFi-RSSI

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***Abstract*—This study investigates a Wi-Fi-based indoor navigation system to determine building locations. The system was developed using the fingerprint method from the Received Signal Strength Indication (RSSI) of each Access Point (AP). The main components of a smartphone-based system use data from Wi-Fi and the Global Positioning System (GPS). The system developed for navigation is designed and implemented as an element of a dynamic, seamless mobility planning and building location route guidance application. Building map data is collected from Google Map data and enhanced by coloring the geographic location of buildings displayed on mobile devices. Navigational aids collected from sensors provide trip orientation and position updates. The approach of measuring the distance between known positions is compared to those displayed in the application with the haversine formula to measure the accuracy of the position displayed. A series of experiments were conducted in the Politeknik Negeri Semarang area, Indonesia. The experiment results showed that the Wi-Fi-based indoor positioning system was accurate within 7.050 meters of the error for that location, thus proving the system's usefulness for determining the location of buildings in the campus area. The measurement has not adopted the maximum APs placement for signal coverage and strength, only using the existing APs positions. The temperature nor humidity was neither measured in each area where the AP was installed, which is discussed later. This system can help visitors without asking, even though they have only visited once.**

***Keywords*— Navigation; RSSI; positioning; smartphone; wireless technologies.**

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I. INTRODUCTION

Indoor location-based services have become very popular due to their extensive and valuable use [1]. In the current smart era, positioning is one of the most essential and promising fields, with applications in both indoor and outdoor surroundings revolutionizing businesses and ushering in new business models [2]. The potential to significantly improve the process of manuals and support decision-making tasks in the field [1], [3]. Other uses are also for security reasons, such as monitoring the position of valuable people or objects insensitive and risky enclosed environments [1], [4]. Indoor positioning applications are widely employed in the domains of sensor networks [5], robotics [6], and navigation systems in the current smart city paradigm [7].

The Global Positioning System (GPS) is the top choice for outdoor positioning, with an accuracy rate of up to 10 m, while indoor localization has no support system. Many researchers have presented different ideas for indoor localization. Using Wi-Fi and cellular communication, such as Place Lab, RADAR, Surround Sense, Sky Hook, etc., is the first system known before [8]. An area with many Wi-Fi Signals would determine the outdoor location as if be a determinant of indoor location. The utilization of Location-Based Services (LBS) has been dramatically developed by utilizing various alternatives to replace GPS that can be used to find out the position, among others, Bluetooth, RFID, Wi-Fi, ZigBee, Micro-Electromechanical Systems (MEMS), Ultra-Wide Band (UWB), and Geomagnetic Field. Expensive implementation is one of the considerations of most of these technologies [9]. Wi-Fi offers significant advantages due to its many existences and already exists in every smartphone device [8], [9].

With the rise of ubiquitous computing, location-aware apps are becoming increasingly important. Smartphones and all their diverse sensors have been discovered and are now being utilized for improved localization approaches. This was obvious in early attempts to use cell phones for geolocation, which relied heavily on infrastructure-dependent pre-5G mobile communications, Wi-Fi, and LoRAWAN [10], [11].

Location determination can be described in 2D space using the received signal strength indicator (RSSI) of at least 3 (three) pieces of Wi-Fi signal in the vicinity identified through basic service set identifier (BSSID). Using RSSI as a range marker is an inexpensive option, as RSSI metrics already exist in most wireless modules on the market. This technique is a good choice to use as a low-cost localization system. RF waves can be used to traverse paths where there are physical obstacles, such as walls or furniture. These disturbances can affect the strength and RSSI [4], [12], [13]. RSSI would depend heavily on temperature and humidity and variations in the value of both [14].

Politeknik Negeri Semarang (POLINES) has 146 Access Points installed in the building around campus. Access Point (AP) utilization is currently only used to serve internet connections. So that the existence of Wi-Fi can be more utilized, one of which is for the help of building navigation. In this article, we recommend reviewing the use of Wi-Fi on campus to help visitors direct and find buildings with the help of smartphone applications.

Location determinant is a way of determining the geographical position of a particular user or device. Its use can determine the user's geographical location and tracking movements. Hence, the determination of the location of the smartphone is moving or not by using the device's capabilities or with additional connectivity support such as GSM, GPS, or Wi-Fi. In the context of LBS, device localization involves a push or pull-type method to find the location, i.e., the device finds the desired location or an external service provider finds the location of the smartphone [4], [15].

Many who have studied and conducted experiments on location determination using mobile phones are growing in the research community [16]. To see the development of research that has been done, it is highly recommended to conduct a survey. Here are some surveys that have been published about localization to be used as a reference. GPS is known to be unsuitable for indoor work, and efforts have been made to determine the location of the room. Surveying non-GPS positioning systems for indoor applications is extensive [13], [17]. That discussion of performance scales such as accuracy, scalability, complexity, and cost may be comprehensive but not always applicable to devices such as smartphones.

Localization with smartphone devices is a device-based scheme with different requirements and challenges than without devices [18]. However, classifying in the category of whether the scheme is device-based or device-free still focuses less on the smartphone's capabilities and fails to develop its full potential. More in-depth research on indoor smartphone localization systems [19] is better, but it should be possible to use it outdoors.

Other research provides a complete network review for location determination, tracking, and navigation [20]. The survey presents mobile localization systems, including the latest results on 5G localization, and solutions based on wireless local area networks, focusing on the ability to calculate 3D locations in multi-storey indoor environments. Discuss physical mapping space in the building to help with tracking and navigation applications. The authors study the latest advances and focus on simultaneous indoor localization and smartphone-based mapping approaches. However, it only provides a very brief and minimal discussion about smartphone-based localization and does not provide a classification scheme.

Sensing-based surveys on cell phones are provided, spanning a variety of application sectors that have been released in the past [21]. The use of several sensors incorporated in current smartphones (high-resolution cameras, microphones, accelerometers, gyroscopes, magnetometers, GPS) and interfacing with external sensors that connect with smartphones through wireless or cable communication technologies are highlighted. However, no precise indoor locations and engineering classifications were further discussed.

Fig. 1 A subset of sensors in smartphones. *Source*: Adapted from [8]

Another study by Li, Cheng, and Chen [22] identified the top 10 indoor localization techniques utilized mostly on construction sites, and each indoor positioning principle and algorithm was assessed and compared using a new performance score. Otero et al. [23] analyzed the most recent mobile interior mapping techniques and compared noteworthy characteristics for architecture and construction. This work also includes categorization in terms of physical configuration and sensor mapping. A survey of wireless developing IoT indoor localization approaches was provided by Kordi et al. [24]. This study compared several strategies in terms of accuracy, resilience, scalability, complexity, and cost. Finally, Shit [25] examines the impact of precise and accurate localization on autonomous navigation systems, as well as the issues and limits of the related algorithms.

This research uses Wi-Fi sensors embedded in smartphones to help navigate building searches by utilizing Access Points installed in POLINES environments. Besides being cheap [26], this method was chosen because the surrounding environment already has Wi-Fi installed and is ready to use its signal strength. Precision-level testing of the user's location determinant is done with a known coordinate measurement compared to the coordinates generated from the application. The results of the precision level can be taken for recommendations for the utilization of Wi-Fi in the Polines area for navigation applications.

II. Materials and Method

A. Preprocessing

Placing an AP that maximizes localization accuracy and coverage simultaneously can improve localization quality [27], [28]. Trilateration is based on the distance between the tag device and some AP with known location coordinates. Knowing the distance to the AP is done by looking at the device along the circumference of the circle centered on the AP, and the radius is equal to the distance of the smartphone-AP. For 2D localization, at least 3 (three) BSSIDs are required to perform trilateration surgery [13]. Using RSSI is one way to measure the distance from the smartphone to the transmitter using a distance relationship with signal-strength [13], [29].

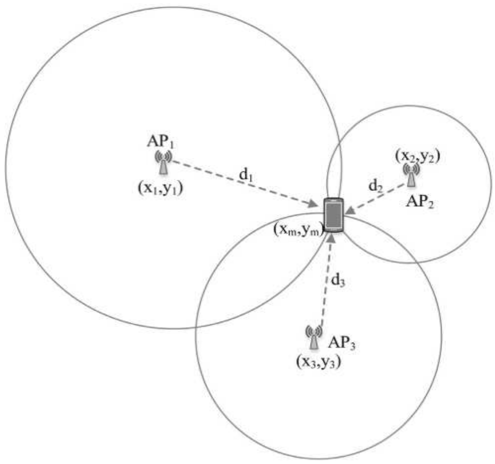

Fig. 2 Trilateration distance representation. *Source*: Adapted from [8]

Wi-Fi or AP installed in the POLINES building as many as 146 pieces. Based on field conditions, the number of Wi-Fi in its implementation only used 65 Wi-Fi points that can be used. Wi-Fi cannot be used on average due to the position of Wi-Fi that is too far from the path that the user would go through to move between buildings. In using RSSI for positioning, the main thing to do is to identify each Wi-Fi by recording every ID on the Wi-Fi. The marker of each Wi-Fi is marked with a BSSID, a MAC Access Point [30].

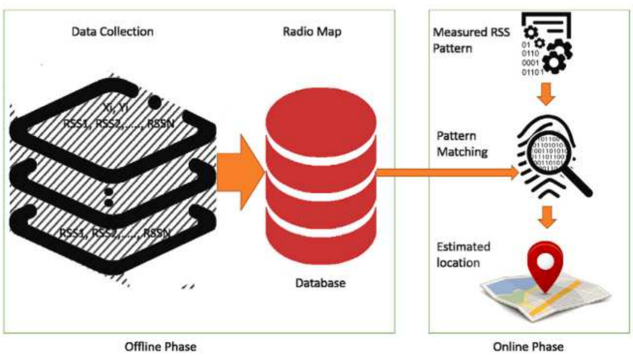

Fig. 3 Radio mapping process. *Source*: Adapted from [8]

TABLE I
POSITION AND BSSID WI-FI AROUND, WHICH CAN BE USED

No	Building Name	Room Location	SSID
1	Old Administration Building (AD I)	North-west corridor	ADI-I-R.DOSEN
2	Old Administration Building (AD I)	Canteen	ADI-I-KANTIN
3	Old Administration Building (AD I)	North hall	ADI-I-HALL
4	Business Administration Building (AD III)	North-west corridor (Kajur AK Door)	ADIII-I-KAJUR-AK
…	…	…	…
65	POS TIMUR	East Post Black Square Parking	POS-TMR

Navigine is a vendor that provides Indoor Positioning System facilities that use sensors found in modern smartphones. Navigine uses Wi-Fi signals and inertial sensors found in smartphones for navigation with a claimed accuracy of 1-2 m [30]. To use Navigine support, applications must be configured in the following steps: (1) add a supported location map (2) add a Wi-Fi transmitter (3) specify the venue destination (4) of building applications with the SDK of Navigine [31].

Fig. 4 Route Configuration, Wi-Fi placement and Venue on Navigine dashboard

Direz is an application running on the Android operating system that has been successfully created by utilizing maps, transmitters, venues, and routes defined in the Navigine configuration. The map is the area that would be handled in the application. The map was obtained from the results of picking up pieces from the POLINES area on Google Maps. A transmitter is a Wi-Fi used by identifying each Wi-Fi with a BSSID (MAC). The venue is the destination that shows the entrance to the building. A route is a path that allows you to go to any location from any position with references according to the map. All of these configurations would be used as determinants of the user's location and determine the shortest route of several route references to reach the intended location. Dijkstra's algorithm is used to determine the shortest route [31].

The experiment was done by taking the position of the coordinate point of the test that is already known (plan) and would be compared with the results of the testing of the coordinate point resulting from the application. The distance (m) of the two components would be used as a reference level of precision or accuracy of the application that has been made. To help determine the accuracy of the results of the formula measuring the distance between two pairs of latitude and longitude points and the resulting distance using Google Maps manually.

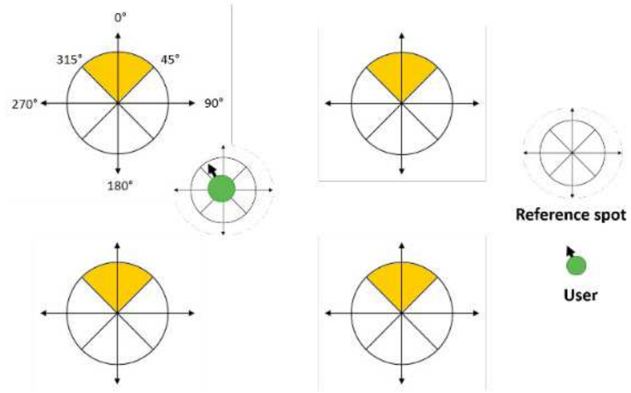

Fig. 5 Reference Spot for direction. *Source*: Adapted from [9]

B. System Architecture

When the application ran, the first step was to display the choice of map to be used, and the user was asked to specify the map to be used. Next, the application would automatically look for the user's position depicted by the marker on the map. The speed of positioning would be affected by signals from multiple Wi-Fi RSSI to perform the Trilateration process. The appearance of user points on the map would show position prediction.

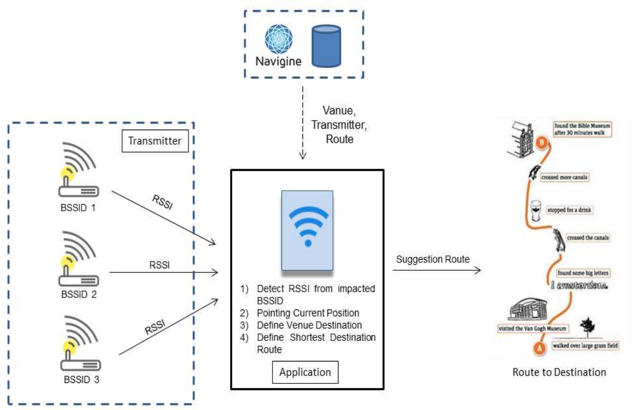

Fig. 6 Direz System architecture

Next, the user determines the building to be addressed from the location where the user stands and would be given the shortest route to reach the location. The route would be described as a line connecting the user's position point to the destination position point. The app would be so responsive to a movement that it would adjust the position on the map automatically when the user is running. The application can make other location determinations after it has finished reaching the destination location or by the user canceling the previous destination location. The destination location option would only be displayed according to what is already configured on Navigine.

C. Distance Determination

To measure the distance between two position coordinate points, appear in the application, and the survey position corresponds to the Google Map coordinates, using the Haversine formula. The Haversine formula is a common method for calculating the distance between two locations. We used the formula for each pair at each test position in both comparable positions to determine the distance in units of meters [32]. As a comparison that the distance generated using the accurate formula, it is then compared to using the "measure distance" feature in Google Maps to determine the precision level.

$$a = \sin^2(\Delta\varphi/2) + \cos \varphi 1 \cdot \cos \varphi 2 \cdot \sin^2(\Delta\lambda/2) \quad (1)$$

$$c = 2 \cdot \mathrm{atan2}(\sqrt{a}, \sqrt{(1-a)}) \quad (2)$$

$$d = R \cdot c \quad (3)$$

where : φ *is latitude,* λ *is longitude,* R *is earth's radius (mean radius = 6,371km);note that angles need to be in radians to pass to trig functions!*

The determination of the survey place is divided into three categories, namely (1) the position of the entrance gate of Polines (Loc_A), (2) the position where the signal is strongest (Loc_B), (3) the position where the signal is weakest (Loc_C). The test results would assess whether the application can run in an environment with various conditions. Positioning of the strong-weak signals to determine the RSSI influence of each BSSID Wi-Fi. The position of the entrance gate is used to test at the position possible most often. The user starts the application. From the test results, the average time of determination of user location and accuracy of the distance of the point appears would be obtained.

TABLE II
COORDINATE POINT OF THE TEST SITE POSITION

No	Recognizable points	Latitude	Longitude	Initial	Category
1	Directorate entrance	-7.051815234	110.4354665	Loc_A	Most used
2	Hallway of Building AD II Directorate with Cooperation Building	-7.052379733	110.4352127	Loc_B	Strong Signal
3	Green Field Near School Building One	-7.052461754	110.4337751	Loc_C	Weak Signal

III. RESULTS AND DISCUSSION

The study focused on the effect of the signal strength received (RSSI) by smartphone devices at each testing site for app usage evaluation. In each position, the experiment uses RSSI as a determinant of the user's location. The introduction of Wi-Fi is done in two phases, the offline phase and followed by the online phase. In the offline phase, reference samples containing the RSSI R values of all detected AP's and reference coordinates from known locations are collected and stored. The collection of reference samples forms a fingerprint database of the surveyed areas has been studied by Rizk, Abbas, and Youssef [15] study.

This test is done to determine if there is a shift between the position of the survey plan and the position of the location specified by the application. The accuracy of the test results would determine the coordinate point of the initial position of the route to the intended place, so that the difference in the distance would have an effect on the convenience of using the application. The results shown in the test on Loc_A has an irregularity value with a value of 13,406 m. This result is influenced by the contribution of BSSID of 3 pieces with an average distance of 30,160 m and with an average RSSI of -73.33 dB. The test results of Loc_B resulted in a distance deviation of 4,918 m which was affected by 3 pieces of BSSID with an average distance of 23,301 m and an average RSSI of -73.66 dB. As for the third location Loc_C produced a distance deviation of 2,827 m with 3 pieces of BSSID with an average distance of 49,535 m and an average RSSI of -88 dB.

TABLE III
WI-FI THAT AFFECTS EVERY TEST SITE POSITION

No	Latitude	Longitude	SSID	Strength (dB)	Dist (m)
Loc_A					
1	-7.051650187	110.4353661	POS INDUK	-68	21.441
2	-7.052100835	110.4356236	ADII I ULP	-74	36.177
3	-7.052096176	110.4353741	ADII II WADIR I	-78	32.862
Loc_B					
1	-7.052424099	110.4353121	ADII I BAKPKs	-68	12.026
2	-7.052167803	110.4353155	ADII II WADIR IV	-72	26.153
3	-7.052384927	110.4349253	GKS I R. KELAS	-81	31.723
Loc_C					
1	-7.052153617	110.4335488	SS III AUDIOTORIUM UTR	-87	42.399
2	-7.0522562	110.4335378	SS III AUDIOTORIUM SLTN	-90	34.756
3	-7.052521599	110.4344198	SIB I BRT	-87	71.451

TABLE IV
APPLICATION TESTING COORDINATE RESULTS

Loc	Recognizable points		Direz Arises	
	Lat1	Lon1	Lat2	Lon2
Loc_A	-7.051815234	110.4354665	-7.051810991	110.4353451
Loc_B	-7.052379733	110.4352127	-7.052374409	110.4351684
Loc_C	-7.052461754	110.4337751	-7.052487042	110.4337778

TABLE V
DISTANCE RESULTS

Loc	Distance (m)	
	Haversine Formula	Google Maps
Loc_A	13.406	13.1
Loc_B	4.918	4.99
Loc_C	2.827	2.22

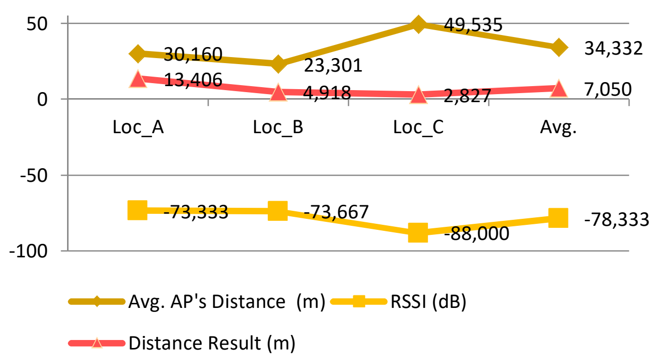

Fig. 7 Comparison of Access point, RSSI, and Error rate distances

If viewed from the three deviation distances from the three locations produced, there would be an average deviation of about 7,050 m.

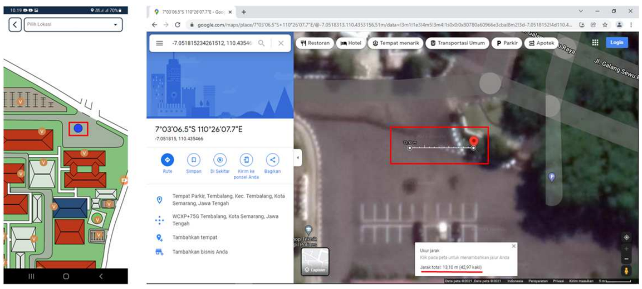

Fig. 8 Manual measurements Loc_A with Google Map

Measurements using google maps are done by comparing two coordinate points from each location with previously known points, as seen in figure 8. The results of manual measurements with Google Maps resulted in the difference in the average distance for the three locations is about 0.280 m when compared to the measurement results with the haversine formula.

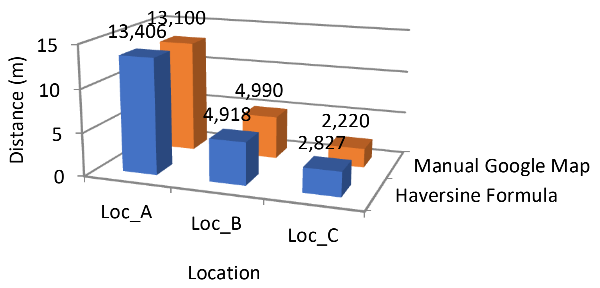

Fig. 9 Distance comparison with different measurement methods

IV. Conclusion

The use of Wi-Fi in the POLINES campus area for building search navigation using a smartphone has successfully shown error rates at each test site. The test site is based on the signal strength and prediction of possible use. Of the three scenarios whose test locations were made obtained the average error rate measurement of user location predictions of 7,050 m. So that research can be continued by adding additional transmitters such as iBeacon in areas that are not reached by signals to increase location determination accuracy. The routes the application generates in the shortest route to get to the destination are very dynamic. The user's position on the map would continuously be updated, and the route is constantly updated by following the user's movements. Navigation applications are still recommended to help visitors search buildings in large areas while maintaining the accuracy of information.

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