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Development of Location-Based Services in Smart Systems: A Literature Review

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Abstract *– Location-Based Services (LBS) are technologies that utilize user location data to provide relevant location-based information. This study aims to examine various LBS applications in smart systems through a review of previous literature. LBS are applied in both outdoor and indoor environments. Outdoor LBS typically use Global Positioning System (GPS) technology for applications such as attendance systems, local business searches, transportation, and healthcare services. Meanwhile, indoor LBS use technologies like Pedestrian Dead Reckoning (PDR) and Simultaneous Localization and Mapping (SLAM) to navigate environments where GPS signals are obstructed. This study also identifies the use of hybrid systems that integrate both indoor and outdoor LBS to ensure consistent service. In addition, challenges related to accuracy, privacy, and energy efficiency in LBS applications across various sectors are discussed. The findings of this research highlight the significant potential of LBS in supporting smart systems while emphasizing the need for further research to address existing challenges, particularly in technology integration and privacy improvements. The implementation of hybrid systems combining indoor and outdoor technologies is expected to provide a more comprehensive solution for future development.*

Keywords – *Location-Based Services; LBS; smart systems; LBS privacy; hybrid systems.*

I. Introduction

LOCATION -Based Services (LBS) refer to technology that leverages user location data to present relevant, location-based information [1]. LBS research is broad, covering both outdoor and indoor LBS applications [2]. Location-based services (LBS) have evolved to cover both outdoor and indoor applications, addressing diverse needs in our mobile information society [3]. While outdoor LBS primarily relies on GPS, indoor positioning remains a challenge, prompting research into various techniques such as WiFi, GNSS integration, and fingerprinting [4, 5]. The development of seamless indoor-outdoor applications and stakeholder-oriented services is a key focus [6]. Indoor LBS are expected to have significant impact, with applications in navigation, marketing, and asset tracking [7]. Research trends include context-awareness, natural interfaces, and interdisciplinary approaches [8]. Challenges persist in positioning accuracy, privacy protection, and scalability of system architecture [9]. Ongoing research addresses indoor positioning, moving object databases, rendering, and web services to advance indoor LBS development [10].

Outdoor LBS applications include remote employee attendance systems, replacing traditional methods like fingerprinting [2,11]. Other outdoor LBS applications assist users in finding local businesses such as car repair shops [12], motorcycle repair shops [13], grocery stores [14], vegetable vendors [15], fertilizer stores [16], photo studios [15, 16], tailoring services [17, 18], construction workers [19], and essential goods stores [20]. In addition, LBS play a significant role in sectors such as transportation [19, 20], tourism, and culinary services [21], offering users route guidance and nearby destination recommendations. In healthcare [22], LBS offers innovative solutions like locating the nearest ambulance, which facilitates faster response times and patient transport. Location-based services (LBS) offer innovative solutions for emergency medical services, including locating the nearest ambulance and facilitating faster response times. Studies have shown that integrating mobile communication and LBS into healthcare systems can improve patient

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outcomes [23, 24]. LBS enables real-time tracking of patient locations and vital signs, allowing for rapid emergency response and remote management of medical data [24, 25]. Implementation of LBS in healthcare systems can help identify the closest medical facilities and determine optimal routes for ambulances [26, 27]. Research has demonstrated that mobile phone use, combined with LBS, has significantly improved ambulance response times in urban areas [28]. LBS technologies integrate GPS, GIS, and wireless communication networks to provide location-related guidance and personalized services for users [29, 30].

Indoor LBS applications enhance convenience across various sectors. For example, in building navigation, Google Maps Indoor guides users to their destinations in shopping malls and hospitals. In smart offices, Cisco Spaces monitors attendance and manages workspace usage. LBS also supports visually impaired individuals with apps like RightHear and helps hospitals in guiding patients. Technology such as Zebra Technologies' real-time asset tracking is used in warehouses, while museums utilize LBS through apps like Smartify to provide automatic information on artworks. In conferences, MeetApp assists participants in navigating venues and accessing agendas.

Indoor LBS typically uses two key technologies: Pedestrian Dead Reckoning (PDR), which relies on smartphone inertial sensors like accelerometers and gyroscopes, and Simultaneous Localization and Mapping (SLAM), which uses smartphone cameras [31].

This literature study aims to explore various applications of LBS in smart systems through a review of previous studies. The paper seeks to identify trends, benefits, and challenges in implementing location-based technologies. Therefore, the study is expected to provide deeper insights into LBS's contribution to smart systems, enhancing efficiency and convenience in various aspects of life in the future.

II. Research Methods

This study employs a literature review methodology to gather and analyze research relevant to LBS applications in both outdoor and indoor environments across various sectors. This approach aims to identify, assess, and synthesize research findings published in scientific journals and conferences. The study follows a Systematic Literature Review (SLR) approach, as shown in Figure 1.

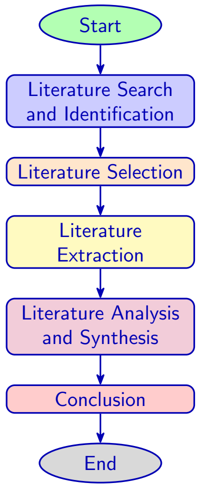

Figure 1: Systematic Literature Review Stages

i. Literature Collection

The initial stage involves collecting literature to identify relevant articles and scientific journals. This is conducted by accessing scientific databases such as Google Scholar, IEEE Xplore, and ScienceDirect. Keywords used include *"Location-Based Service"* and *"Layanan Berbasis Lokasi."* Collected articles must meet certain criteria: published within the last five years (2020–2025) and highly relevant to the LBS topic, whether in outdoor or indoor applications. Only articles meeting these criteria are considered for further analysis.

ii. Literature Selection

The next stage involves selecting literature based on established inclusion and exclusion criteria. Selected articles must be published in English or Indonesian and accredited at least SINTA or equivalent. Additionally, the articles must be significantly relevant to LBS implementation. After the selection process, 61 articles relevant to the research topic were obtained. The selected articles are listed in Table 1 as the primary references for this study.

Table 1: Literature Search Results from Scientific Databases

No.	Database	Number of Articles
1	Google Scholar	42
2	ScienceDirect	10
3	IEEE Xplore	9
Total		**61**

iii. Literature Extraction

After selection, literature extraction is conducted to obtain key information from the selected articles, such as titles, author names, publication years, and LBS categorization strategies. The extraction aims to identify LBS applications in two main categories based on service location (indoor and outdoor) and various sectors involved. The categorization results are presented in two tables and visually represented in a pie chart: Table 2 outlines LBS services by location, and Figure 2 illustrates the percentage distribution of LBS research by type (Outdoor, Indoor, and Combined Indoor-Outdoor LBS). The categorization results are presented in Table 3, which shows sector-based categorization, and visually summarized in Figure 3.

Table 2: LBS by Service Location

No.	LBS Services by Location	Number of Articles
1	Outdoor LBS	42
2	Indoor LBS	10
3	Combined Indoor and Outdoor LBS	9
Total		**61**

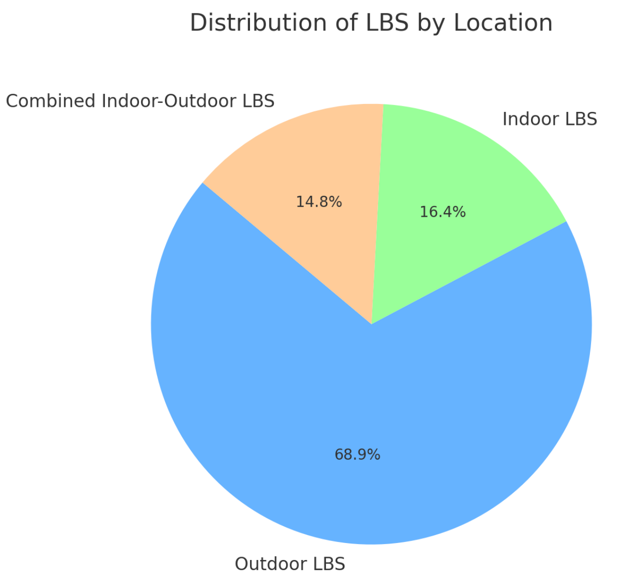

Figure 2: Pie chart illustrating the distribution of Location-Based Services (LBS) research by location type: Outdoor LBS (68.9%), Indoor LBS (16.4%), and Combined Indoor-Outdoor LBS (14.8%).

Table 3: LBS by Sector Categorization

No.	LBS Based on Sector Categorization	Number of Articles
1	Attendance	7
2	Local Business	11
3	Security	4
4	Health	2
5	Tourism and Culinary	9
6	Transportation	3
7	Environment and Social	4
8	Technology and Innovation	24
Total		**61**

iv. Literature Analysis and Synthesis

The next step involves analyzing and synthesizing literature to identify patterns and trends from various LBS strategies implemented in previous studies. The analysis is conducted qualitatively by categorizing findings based on technology type and methods used. Additionally, the effectiveness of each LBS strategy is compared to identify strengths and limitations. The primary findings on LBS implementation in various sectors, such as attendance, local business search, transportation, security, and healthcare, will be discussed in depth in the results and discussion sections. This process aims to provide a comprehensive view of the technologies used and recommendations for future development.

The final part of this study compiles conclusions and recommendations based on literature synthesis results. The conclusions will summarize key findings regarding LBS applications, both in indoor and outdoor settings. Additionally, this research provides practical recommendations for more effective LBS utilization, particularly in supporting smart systems. This study aims to answer questions regarding the most effective strategies for implementing LBS, considering location and the various methods employed. Therefore, this study is expected to contribute significantly to the development of LBS technology and future research directions.

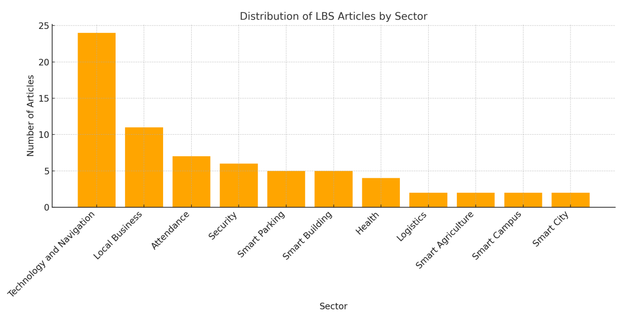

Figure 3: Distribution of LBS Articles by Sector.

III. Results and Discussion

The literature review identifies 61 articles relevant to LBS applications, which are classified into three primary categories: LBS by service location, LBS by sector grouping, and LBS implementation development methods.

i. LBS by Service Location

In the location-based classification, numerous researchers have conducted studies related to LBS. This review categorizes location determination into three groups: outdoor LBS, indoor LBS, and combined indoor and outdoor LBS.

Outdoor LBS is a location-based service used in open spaces, typically utilizing Global Positioning System (GPS) technology for high-precision location determination. Various studies have examined outdoor LBS, such as a 2020 security sector study by Novia Alvira Julita *et al.* [32] focused on developing crime reporting systems and another by Risnu Arya Kusuma *et al.* [33] on traffic sign alert applications.

In 2021, Winda Suci Lestari Nasution [34] developed a fitness center search application in Purwakarta Regency for the healthcare sector. M. Budi Hartanto and Yodhi Yuniarthe [35] in 2022 created an LBS app for locating tourist spots in Tanggamus Regency. In 2023, Suprapto [36] and Rasyid Noor Imamsyah [37] developed applications to facilitate public transport searches for drivers and passengers.

This research continued in 2024 with Rois Almunthaza *et al.* [12] creating a nearby car repair shop locator and Muhammad Arif Triyandi and Muntahanah [14] focusing on a confectionery store locator in Bengkulu city. In the same year, A. Asrul *et al.* [38] and Tri Arvianto [11] developed a location-based attendance system to improve employee attendance management accuracy.

Indoor LBS determines a user's location within indoor environments where GPS signals are typically obstructed by building structures. Therefore, indoor LBS commonly employs supplementary methods.

A 2023 study by Wanting Li *et al.* [39] focused on a smartphone-based crowdsourcing indoor LBS, while a 2024 study by Hitesh Verma *et al.* [40] emphasized security and privacy in device sensor data usage for indoor LBS. In 2025, Anwar Hamadi and Abdelhakim Latoui [31] developed a pedestrian location service using smartphones.

These studies utilized Pedestrian Dead Reckoning (PDR), which employs smartphone sensors such as accelerometers and gyroscopes to track movement, and Simultaneous Localization and Mapping (SLAM), specifically ORB-SLAM, which uses smartphone camera data to determine position and map the surrounding environment.

Combined indoor and outdoor LBS integrates technology for consistent location determination across indoor and outdoor environments. For example, a 2022 study by Zhao Shi *et al.* [41] focused on both indoor and outdoor location systems, followed by a 2024 study by Yongyi Mao *et al.* [42] on indoor and outdoor location systems using the cuckoo search (CS) algorithm, utilizing a GPS and Wi-Fi combination.

Other studies include work by Kaiqiao Tian and Khalid Mirza [43] in 2022, which aimed to improve robot navigation and location understanding, and a 2024 study by Youssef Keryakos *et al.* [44] introducing a hybrid navigation system concept to assist visually impaired users in navigating both indoor and outdoor environments.

Each of these LBS categories provides specific solutions based on user environment needs, with outdoor LBS focused on outdoor accuracy, indoor LBS providing indoor solutions, and combined systems ensuring consistent service experiences.

ii. LBS by Sector Grouping

Several sectors utilizing LBS in prior research are listed in Table 4.

Table 4: LBS by Sector Grouping

No	Sector Grouping	Article	Total
1	Attendance	[11], [38], [45], [46], [47], [48], [49]	7
2	Local Business	[12], [13], [14], [15], [16], [17], [18], [50], [51], [19], [20]	11
3	Security	[32], [33], [52]	3
4	Health	[22], [34], [44], [53]	4
5	Tourism and Culinary	[21], [35], [54], [55], [56], [57]	6
6	Transportation	[36], [58], [37]	3
7	Environment and Social	[35], [59], [60]	3
8	Technology and Navigation	[1], [31], [39], [40], [41], [42], [43], [61], [62], [63], [64], [65], [66], [67], [68], [69], [70], [71], [72], [73], [74], [75], [76]	24

Table 4 shows that LBS has high appeal in technology, navigation, and local business sectors, reflecting its potential in supporting technological innovation and aiding local business development. Conversely, security, transportation, and environmental sectors appear underexplored, indicating further research opportunities given the relatively lower number of studies.

iii. LBS Implementation Development Methods

LBS methods and technologies are diverse, encompassing various approaches to improve system accuracy and efficiency. Several methods are drawn from literature reviews in prior research, as listed in Table 5 for outdoor LBS development methods.

Table 5: Outdoor LBS Development Methods

No	Outdoor LBS Development Methods	Article Citations	Total
1	Rapid Application Development (RAD)	[14], [19], [34]	3
2	Waterfall	[13], [15], [51], [20], [36], [34], [35], [45], [46], [54], [55], [56], [77], [75]	14
3	Haversine	[38], [16], [50], [32], [33], [37]	6
4	Prototype	[18], [47], [68], [73]	4

iv. Rapid Application Development (RAD)

RAD is a software development method focused on reducing design and implementation time, yielding short development cycles [19]. The stages of RAD are shown in Figure 4.

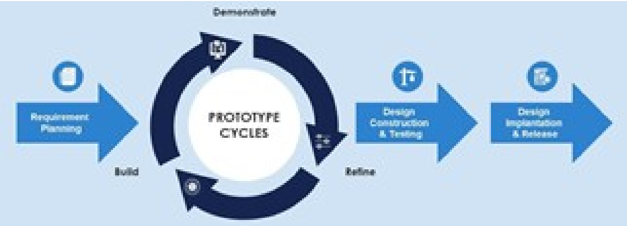

Figure 4: Stages of RAD

In the requirement planning stage, developers gather the basic needs of users for Location-Based Services (LBS). This involves identifying relevant features such as location tracking, location-based notifications, and map display. Direct feedback from potential users is also collected to ensure their needs are met within the application.

In the prototype cycles stage, after gathering requirements, developers create an initial design or prototype of the LBS system. In this phase, main elements like user interface and location data architecture are designed. The initial prototype is developed to illustrate how users will interact with the application and to evaluate key functional elements.

In the design construction & testing stage, iterative development is conducted to build core LBS functions, such as location tracking accuracy, integration with digital maps, and location-based notifications. Each update is tested based on user feedback to ensure that the application aligns with user needs. This iteration helps refine and optimize the LBS application before the final launch.

In the final stage, design implementation & release, once the prototype meets user needs, the LBS application is ready for implementation. Tests are conducted to ensure stability, location accuracy, and performance in real-world conditions. Final user feedback serves as a guide for further improvements and adjustments to the system.

The advantage of the RAD method is its more efficient development stages compared to other models, making the overall development time shorter. This efficiency comes from the reuse of existing components, which saves time. However, a downside of this method is that not all applications are suitable for RAD. If the system cannot be modularized properly, essential components in RAD development may face challenges.

v. Waterfall Method

The Waterfall method is a traditional system development approach that requires each phase to be completed in a sequential order. This model is also known as the traditional or classic model [77]. It consists of the following stages: Communication, Planning, Modeling, Construction, and Deployment [45]. The stages of the Waterfall method are shown in Figure 5.

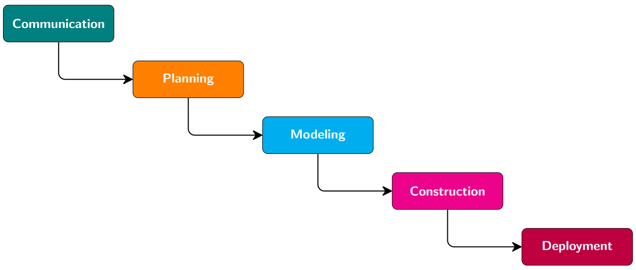

Figure 5: Stages of the Waterfall Method

The **Communication** stage involves identifying needs and problem analysis through direct communication with stakeholders. In this phase, the requirements for an LBS-based system to monitor user location or attendance are identified, including technologies like GPS and cellular connection.

The **Planning** stage focuses on gathering and organizing resources, as well as estimating the time and cost for each phase. Developers plan the best way to build an LBS system that facilitates location search and determination with high accuracy.

The **Modeling** stage is where the system design and workflow begin to be developed using flowcharts and data models that support LBS functions. The application interface is also designed to allow users to access location data interactively and in real time.

The **Construction** stage is the implementation of code and initial testing, carried out according to the prepared design. In this phase, core LBS features, such as data acquisition through GPS and integration with digital maps, are developed and tested to ensure each component functions properly.

The **Deployment** stage is the final phase, where the developed system undergoes comprehensive testing to ensure there are no errors or bugs. Testing is conducted using the blackbox method, covering all application functions, such as location logging and user position mapping. Once all functions are verified and validated, the application is launched and ready for user use.

The advantage of the Waterfall model is that it is easy to understand, with clear stages and stability in identified requirements. This model also simplifies project management because nearly all requirements are identified and documented, making the process easier to understand for both the team involved and the project owner. However, a disadvantage of this model is its sequential and linear nature, making it difficult to go back to a previous stage, and it lacks flexibility for changes.

vi. Haversine Method

The Haversine formula calculates the distance between two Earth points based on latitude and longitude coordinates, which is essential in navigation and location services [37].

vii. Prototype Method

Prototyping quickly gathers information about user needs through iterative evaluations, allowing minimized errors and potentially higher complexity due to continual refinement [47]. This method has the advantage of accurately identifying needs through periodic evaluations. Thus, errors can be minimized. However, this method also has a drawback: it can lead to higher complexity due to ongoing refinements, which may result in increased costs.

Table 5 shows that the Waterfall method dominates outdoor LBS development, appearing in 14 articles due to its structured approach, ease of project management, and comprehensive documentation. The Prototype and RAD methods emphasize speed and flexibility, allowing rapid feedback from end-users to better align with user needs.

The Haversine method, discussed in 6 articles, highlights the importance of geolocation in LBS development. This method focuses on calculating distances between points on the Earth's surface, which is essential for various LBS applications, such as navigation, location searches, and other location-based services.

Overall, the methods used reflect the need to adapt development approaches to the specific goals and contexts of LBS projects. The Waterfall method may be better suited for stable projects, while Prototype and RAD offer more responsive solutions to user needs. Additionally, integrating geolocation aspects, as demonstrated by the Haversine method, becomes an essential element that cannot be overlooked in designing effective LBS solutions.

viii. Indoor LBS Development Methods

PDR (Pedestrian Dead Reckoning) uses smartphone sensors to estimate movement [33], while SLAM (Simultaneous Localization and Mapping) provides simultaneous mapping and localization [31].

A2L (Align-to-locate) is a technique using Building Information Models (BIM) as a reference to enhance indoor positioning accuracy [69]. It aims to reduce positioning system errors that often occur due to complex indoor environments.

Table 6: Indoor LBS Development Methods

No	Indoor LBS Development Methods	Article Citations	Total
1	PDR (Pedestrian Dead Reckoning), SLAM	[31], [33], [67]	3
2	A2L (Align-to-locate)	[69]	1
3	Dead Reckoning, Triangulation, Trilateration	[70]	1
4	M-RSC (Modified Ring-Stepping Clustering)	[62]	1
5	SRS (Spatial-tagged Radio Mapping System)	[63]	1
6	ILS, SRS	[1]	1
7	DT (Digital Twin), ML (Machine Learning)	[64]	1
8	ECA (Enhanced Cloaking Algorithm), BLH	[71]	1

Dead Reckoning utilizes data from a smartphone's internal sensors (e.g., accelerometers and gyroscopes) to calculate changes in position. This includes triangulation and trilateration techniques to determine the user's position via signal angles and distances [70].

M-RSC (Modified Ring-Stepping Clustering) is designed to extract structural lines from laser point clouds in indoor environments [62].

SRS (Spatial-tagged Radio Mapping System) combines LiDAR and smartphones to create spatial and radio maps in real-time [63]. ILS (Indoor Localization Systems) also integrates with SRS for determining object positions indoors [1].

DT (Digital Twin) creates a digital representation of physical objects to unify data representation. ML (Machine Learning) enhances this by recognizing patterns in user movement [64].

ECA (Enhanced Cloaking Algorithm) hides a user's location context during service access, while BLH (Balanced Location Hiding) ensures performance and load balancing during cloaking [71].

Indoor LBS development showcases the importance of advanced technologies like SLAM, PDR, and Digital Twin to increase localization accuracy. Simultaneously, privacy concerns are addressed through algorithms such as ECA and BLH, underlining the necessity for both performance and security in smart system environments.

ix. Indoor and Outdoor LBS Development Methods

Development methods for indoor and outdoor LBS applications have been widely explored in various studies. These studies focus on developing technologies that enable accurate and efficient positioning in different environments, both indoors and outdoors, as shown in Table 7.

GPS (Global Positioning System) is a satellite-based navigation system enabling location tracking on Earth's surface 24/7 [15]. GNSS (Global Navigation Satellite System) encompasses GPS and other satellite

Table 7: Indoor and Outdoor LBS Development Methods

No	Indoor Technology	Outdoor Technology	Articles
1	WIFI	GPS	[41], [65]
2	Sensor Fusion	GPS	[43], [44]
3	UWB	GNSS	[65]
4	BLE	GNSS	[66]
5	MSL	GNSS	[67]
6	DL-TDOA	GPS	[61]

systems and is ideal for outdoor positioning, although it can be obstructed by tall buildings [65].

DL-TDOA (Deep Learning Time Difference of Arrival) enhances TDOA accuracy by integrating deep learning techniques [61]. WIFI is used indoors to match access point signals with device locations, overcoming GPS limitations [41].

Sensor Fusion combines multiple sensor data sources to improve accuracy and reliability, enabling better navigation and localization [43]. UWB (Ultra Wideband) provides high-speed and high-accuracy indoor positioning where GNSS signals are weak [65].

BLE (Bluetooth Low Energy) enables low-power, short-range communication and improves positioning accuracy using beacon signals [66]. MSL (Mean Sea Level) is used to calibrate altitude readings from barometric sensors for more precise elevation positioning [67].

The choice of LBS development method depends on project characteristics and user needs. WiFi and UWB are best for indoor areas requiring precise accuracy, while GPS and GNSS are preferred for outdoor applications. Hybrid systems combining multiple technologies promise comprehensive solutions by overcoming the limitations of each method.

Future research should focus on optimizing hybrid integration to develop more efficient, accurate, and robust location determination systems suitable for both indoor and outdoor environments.

IV. Conclusion

This literature review demonstrates that Location-Based Services (LBS) play a crucial role across various sectors. Outdoor LBS supports applications such as attendance systems, local business searches, security, healthcare, transportation, tourism, and culinary services. Meanwhile, indoor LBS applications face accuracy challenges, but technologies like Ultra Wideband (UWB) improve precision, achieving DRMS of 5.25 cm and RMSE of 10.18 cm. Bluetooth Low Energy (BLE) also enhances indoor accuracy to over 95%, with a maximum error below 0.5 meters. BLE and Wi-Fi are more cost-effective than UWB and more power-efficient than GPS, making them ideal for long-term use. In addition to improved accuracy and efficiency, LBS privacy and security are also enhanced. Algorithms such as the Enhanced Cloaking Algorithm (ECA) and Balanced Location Hiding (BLH) increase privacy success rates up to 98%. Hybrid systems combining GPS, Wi-Fi, and sensor fusion with the Cuckoo Search (CS) algorithm improve service reliability, reducing location failures by up to 17%. However, challenges related to accuracy, privacy, and system integration persist. The future development of hybrid systems is expected to offer more complete solutions to these issues.

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