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# Systematic Literature Review: LoRa and LoRaWAN Projects in Practice

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## ABSTRACT

The first technology to communicate with the Wireless Sensor Network (WSN), but this technology can only perform close-range sensing and processing, in contrast to the Internet of Things (IoT) which can communicate long distances based on the Internet, while the commonly introduced assistive technology is Low-Power-Wide-Area-Network (LPWAN) which is a low power consumption technology but long range. One technology that is widely used is LoRa and its open access utilises LoRaWAN, because it has many advantages. There has been a lot of research on LoRa, LoRaWAN and surveys or reviews, but not many have focused on reviews for application rather than just testing. In this research, the author wants to conduct a review of the application of LoRa and LoRaWAN by utilising Systematic Literature Review (SLR), with the initial phase search getting 1314 and the final result is getting 45 studies taken from IEEE Explorer, ACM and Indonesian language papers (Google Scholar). Then the researcher presents a discussion related to the application of LoRa and LoRaWAN in several fields such as health, agriculture, etc.

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## 1. INTRODUCTION

One of the latest technologies such as Wireless Sensor Network (WSN) which works using sensors which communicate with each other between nodes, where many components are contained in it and focus on wireless technology. In fact, technology has developed greatly from the side (Huber et al., 2018). Where sensors are very helpful in sensing and capturing information (Krause and Guestrin, 2009). Sensors used in the surrounding environment have advantages because of their very fast performance, have hardware, and can perform optimization (Bollipo et al., 2020). This WSN technology is a new wireless communication and price reduction has enabled new uses for wireless sensor network devices (Saari, 2018).

If WSN can only communicate with its surroundings via wireless while the Internet of things (IoT) is the biggest part again, because IoT has all WSN devices added with the internet, but due to some weaknesses IoT needs help from the latest technology such as Low-Power-Wide-Area-Network (LPWAN).

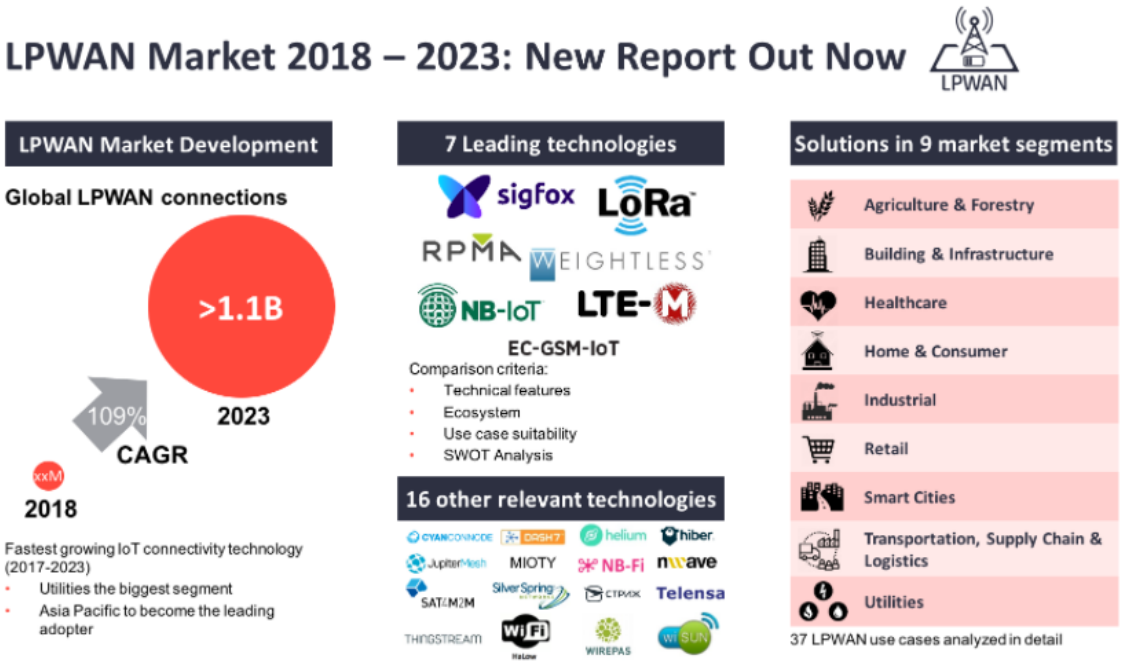


**Figure 1.** Types and Market of LPWAN (see https://iot-analytics.com/ )

As in **Figure 1**, It is likely that the use of LPWANs will continue to increase from 2018 - 2023, and the segments that can be helped are agriculture, healthcare, home, industry, etc (Malik et al., 2021). But only a few technologies will lead the advancement of this technology, and only 16 technologies are likely to be relevant components.

Technology (LPWAN). This technology is introduced as a technology with long transmitting power and efficient energy usage (Chen et al., 2018). LPWAN has various types of technologies, such as; NB-IoT, Sigfox, LTE-M and LoraWAN, Wi-Fi HaLow (IEEE 802.11ah) and White-Fi (IEEE 802.11af).

According to cloud computing (see https://cloudcomputing.id) NB-IoT is one of the LPWANs which is one of the 5G technology roadmaps in Telkomsel which is made for broad machine-to-machine communication with a wide range of connectivity when compared to GSM. This technology is also capable of having a battery capacity that can last up to 10 years.

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Sigfox technology is based on two modulations, utilising differential binary phase-shift switch (DBPSK) and Gaussian frequency-shift keying (GFSK) modulations that can communicate using a specific bandwidth as applied to the scientific, industrial, and medical sectors (Staikopoulus et al., 2020). But of the two technologies that are most widely used are LoRa and LoraWAN. Because this technology is better in terms of general technology, transmitting power and battery requirements (Petäjäjärvi et al., 2017). LoraWAN itself is an open standard built by the LoRa Alliance, where Long Range (LoRa) itself was developed by semtech technology (Thoen et al., 2019).

LoRa has modulation based on variations of chirp spread spectrum (CSS) and spread spectrum techniques (De Almeida et al., 2021). LoRa can typically operate in Industrial, Scientific, and Medical (ISM) bandwidths for example the frequencies used are (USA: 915MHz, EU: 433MHz, and 868MHz) (Saari, 2018). Given the need for low-power long range is very useful for technology, LoRa is widely used because of its far transmitting power that can even transmit up to 50 km (Centenaro et al., 2016), after sending the data is taken the data is processed at the gateway which will transmit the data to the internet. After that the data can also be processed. Therefore, according to the author, this function can help IoT in obtaining data that manages a lot of data (Yan et al., 2022).

There has been a lot of research on the use of LoRa and LoRaWAN, for technology, especially in agriculture, but there is still rarely research on reviews or systematic reviews related to all uses of this technology. many reviews related to research are still in the research sector only. Many research reviews can be done such as using (Liberati et al., 2009) Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) (Knobloch et al., 2011), or utilising Systematic Literature Review (SLR) (Kitchenham, 2004; Kitchenham, 2009). For some studies, Kitchenham's stages were used.

It is still rare to conduct research that reviews LoRa and LoRaWAN technology for its application (Sanchez-Iborra et al., 2018; Faber et al., 2020). The point of application is, the use that must be applied from various fields. Not just theory but its application can directly become an application for commercialisation and get new ideas in research.

In Introduction Section this is the author's background for writing, in Method Section will be explained how the systematic review method with certain stages. In Result and Discussion Section, the results and discussions will be presented based on the focus carried out by the author. In Conclusion Section, the conclusion of this research will be explained.

## 2. METHODS

Basically, to do the review previously described there are many ways but this research focuses on utilizing SLR from (Kitchenham, 2004; Kitchenham, 2009), by utilising the pattern carried out by (Khan et al., 2017), so that it contains 3 stages namely; planning, implementation and reporting. Using this pattern will make it easier for the author to find suitable studies in the application of LoRa and LoRaWAN.

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**Table 2** Stages of SLR.

| Phase | Stage |
|---|---|
| Planning | - Research Question<br>- Data Resource<br>- Search String<br>- Inclusion and Exclusion Criteria<br>- Quality Criteria for Research Selection |
| Implementation | - Primary Research Selection<br>- Data Extraction<br>- Data Syntetis |
| Reporting | - Documentation and Extraction Result |

## 2.1. Planning

a. Research Question
This research question is carried out in several stages, namely.
1. RQ1 = How to find Research about LoRa and LoRaWAN
2. RQ2 = How to find a mapping of research years of LoRa and LoRaWAN implementation
3. RQ3 = Which publications the application of LoRa and LoRaWAN comes from

b. Data Source
The repository of this research will come from
1. IEEE Explorer
2. ACM Digital Library
3. Indonesian Language Paper (Google Scholar), For google scholar used to search in Indonesian.

c. String Search
This research uses Boolean functions such as AND and OR and filters with examples such as (LoRa Implementation AND LoRaWAN Implementation) OR (LoRa AND LoRaWAN)

d. Inclusion and Exclusion Criteria
For inclusion, the research must be from 2019-2022 and can be written in Indonesian and English. For Exclusion is Research that does not talk about LoRa and LoRaWAN at all

e. Quality Criteria for Research Selection
The assessment criteria of the selected articles are in accordance with the following criteria.
1. Whether the research can answer the research question
2. Does the research talk about LoRa and LoRaWAN?
3. Does the research focus on the application of LoRa and LoRaWAN?
4. Does the research relate to the research question?

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### 2.2 Implementation

a. Primary Research Selection

The research focuses on using the toolgate approach suggested by (Afzal et al., 2009) and follows the pattern of (Khan et al., 2017). Based on the phases below:

1. First Phase : search for relevant articles
2. Second Phase : inclusion and exclusion based on title and abstract.
3. Third Phase : inclusion and exclusion based on introduction and conclusion.
4. Fourth Phase : inclusion and exclusion based on full text.
5. Fifth Phase : final selection will be done reporting.

f. Data Extraction

Self-extraction of the previous phase from phase 1 - the last phase is phase 5

b. Data Syntesis

This stage is the stage before Main reporting, so this implementation phase is the most important phase in the implementation of searching for SLRs

### 2.3 Reporting

a. Documentation and Extraction Result

At this stage, reporting and documentation or discussion of what will be done and discussion of what is produced is carried out.

## 3. RESULT AND DISCUSSION

### 3.1. Result

After performing the steps in session 2, the results and process of performing SLR according to (Afzal et al., 2009) and following the pattern of (Khan et al., 2017) will be described in this section. As in session 2, the results will be attached according to table 1 below.

**Table 1.** Toolgate Approaching Result

| Database | First Phase | Second Phase | Third Phase | Fourth Phase | Fifth Phase | Percentage of research take-up |
|---|---|---|---|---|---|---|
| IEEE Explore | 611 | 455 | 231 | 124 | 30 | 66,77 |
| ACM Digital Library | 44 | 40 | 32 | 15 | 6 | 13,23 |
| Google Scholar | 659 | 532 | 205 | 68 | 9 | 20 |
| Total | 1314 | 1027 | 468 | 207 | 45 | 100 |

According to **Table 1**, the results of each research phase where phase 1 is the phase of searching for research from various amounts there are 611 from IEEE Explorer and 44 from ACM and the remaining 659 Indonesian-language research on google scholar. In accordance

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with the search criteria, an important factor is LoRa technology that can be applied (not just simulations etc.). In **Table 2** is the answer to the research question in the form of years of research obtained.

**Table 2.** Year Result

| Year | Number of paper |
|---|---|
| 2019 | 9 |
| 2020 | 12 |
| 2021 | 20 |
| 2022 | 4 |

**Tabel 3.** Result based on type.

| Publisher Type | Number of paper |
|---|---|
| IEEE Explorer | 30 |
| ACM | 6 |
| Indonesian Language Paper (Google Scholar) | 9 |
| Total | 45 |

**Table 2** and **Table 3** explain the publication questions from what year and where the publication came from. So that researchers or industry can utilise the research to get breakthroughs or new ideas.

### 3.2. Discussion

The Lora research conducted by the author is very specific because it starts from 2019-2022 which focuses on the application of Lora, such as the following Health Research (Taleb et al., 2022) etc. According to the author, health is an important factor, especially now that there is a pandemic, where technology is used as much as possible for the benefit of health, one of which can take advantage of LoRa.

After that, for example, there is research on the environment, rivers, agriculture, irrigation, and food as in (Kosnin et al, 2021; Sari, 2021) etc. Which is a very useful technology for everyone. Lora technology is an application technology that can improve the economy in terms of the environment and its surroundings.

Some research can also be used to help other technologies such as IoT or specialised SMART-focused properties such as (Nafi'ah et al, 2021) etc. So, the application of Lora can be used to help other technologies such as IoT and SMART. So, the application of lora can be used for the latest technology, as long as it is utilised properly. If you look again, the author provides suggestions as a reference for these studies to become material for other researchers or the industry.

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So that researchers in this discussion suggest that if the review of this research can help researchers and related industries to utilise Lora, not only as communication. But utilised for a better area.

## 4. CONCLUSION

Research on LoRa technology has been a very abundant subject, especially in its signalling utilisation as well as LoRaWAN's ability to facilitate communication between devices. LoRa technology itself is a variant of Low-Power Wide Area Network (LPWAN) that is capable of being used in remote areas and requires low power consumption. This provides advantages that other technologies such as NB-IoT and Sigfox do not have. To compile a review, the author is interested in utilising the Systematic Literature Review (SLR) method because this method has proven to be suitable for implementation and relatively easy to do. In the initial stage, the author retrieved research data from various sources such as IEEE Explorer, ACM, and Indonesian Paper (Google Scholar).

As a result, there were a total of 1314 relevant studies. However, to ensure quality and relevance, the authors selected 45 papers which later became the main focus of this review. The details are 30 papers from IEEE Explorer, 6 papers from ACM, and 9 papers in Indonesian found through Google Scholar. After conducting an in-depth analysis, the author also held several discussions related to this research, considering that the most important use of LoRa and LoRaWAN occurs in the fields of health, environment, and as an auxiliary in other technological advancements. It is hoped that this review can benefit researchers and industry, so that they can adopt some of the advancements contained in this review for further progress.

In addition, this review also identifies some important findings that emerged from the selected research. In the healthcare field, LoRa has been used for remote patient surveillance, environmental temperature and humidity monitoring in hospitals, and secure medical data transmission. In the environmental sector, LoRa technology has helped in air quality monitoring, smart waste management, and hydroponic garden monitoring. In addition, the research also highlights LoRa's contribution in supporting other technological advancements, such as in the development of intelligent transport systems, smart power grids, and Industry 4.0 applications. With this review, it is hoped that researchers and industry can dig deeper into the potential utilisation of LoRa in various fields and expand the scope of existing research, along with technological developments and community needs.

The review concludes that LoRa technology, along with its implementation through LoRaWAN, has demonstrated significant potential and benefits in various fields. The selected papers have showcased the versatility of LoRa in addressing challenges and providing innovative solutions. The findings reveal the wide range of applications in the healthcare sector, where remote patient surveillance and secure medical data transmission have enhanced patient care and monitoring. The use of LoRa for environmental monitoring has contributed to better air quality control, efficient waste management, and optimized hydroponic garden systems.

Moreover, the review emphasizes the supportive role of LoRa in advancing other technological domains. The integration of LoRa technology has facilitated the development of intelligent transport systems, enabling real-time data transmission for traffic management and vehicle tracking. LoRa's contribution to smart power grids has enhanced energy distribution and management, promoting sustainable practices. Furthermore, LoRa has played a pivotal role in the implementation of Industry 4.0 applications, enabling seamless connectivity and data exchange between machines and systems.

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The comprehensive review encourages further research and industry adoption of the advancements highlighted in the selected papers. By exploring the potential utilization of LoRa in various fields and considering evolving technological developments and community needs, researchers and industry professionals can harness the capabilities of LoRa to drive further progress. The review serves as a valuable resource for those seeking to understand the current state of LoRa technology and its potential for innovation and advancement in diverse domains.

In addition, the review underscores the importance of LoRa technology's low-power consumption and long-range capabilities, which make it particularly suitable for remote and inaccessible areas. This aspect opens up opportunities for deploying IoT devices and networks in previously challenging environments, enabling connectivity and data gathering where traditional communication technologies fall short. The cost-effectiveness of LoRa further adds to its appeal, as it allows for scalability and widespread adoption across various sectors.

Furthermore, the review highlights the need for continued collaboration between academia, industry, and policymakers to further unlock the potential of LoRa technology. By fostering partnerships and knowledge sharing, researchers and industry professionals can address the existing gaps and challenges in implementing LoRa-based solutions effectively. Additionally, policymakers play a vital role in creating a conducive regulatory environment that promotes the widespread adoption of LoRa technology, ensuring its seamless integration into existing infrastructure and supporting its growth in different sectors. By collectively exploring and expanding upon the findings and recommendations presented in this review, stakeholders can harness the full potential of LoRa and contribute to the advancement of IoT applications and innovations.

Moreover, the review highlights the need for continued research and development to further enhance the capabilities of LoRa technology. While the selected papers provide valuable insights and advancements, there are still opportunities for refining and optimizing the performance of LoRa networks and devices. Areas such as network scalability, interference mitigation, and security protocols can benefit from ongoing research efforts.

Furthermore, the review emphasizes the importance of addressing the potential challenges and limitations associated with LoRa technology. Factors such as network coverage, signal propagation in urban environments, and interoperability with other communication protocols require careful consideration. By identifying and addressing these challenges, researchers and industry professionals can work towards improving the overall reliability and efficiency of LoRa networks, ensuring their seamless integration and interoperability with existing infrastructure and systems.

Overall, this comprehensive review showcases the vast potential of LoRa technology and its impact across multiple domains. It serves as a valuable resource for researchers, industry practitioners, and policymakers, offering insights into the various applications, benefits, and future directions of LoRa and LoRaWAN. With further research, collaboration, and innovation, LoRa technology can continue to revolutionize the way we connect and communicate in the Internet of Things era, driving advancements and improving the quality of life in numerous fields.

## 5. AUTHORS' NOTES

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirm that this paper is free from plagiarism.

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