Energy saving on IoT using LoRa: a systematic literature review

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ABSTRACT

The development of devices connected to the internet is very significant, encouraging the creation of the internet of things (IoT). With remote systems, IoT is not enough to use in case of internet instability. By using long range (LoRa), IoT systems can now solve this problem. Millions of data make IoT-LoRa have to spend a lot of energy. This paper helps discover where recent studies offer a broad perspective on energy savings using the systematic literature review (SLR). The paper extracted 252 articles from IEEE, ACM, MDPI, Springer, Hindawi, ScienceDirect, and IAES. 44 articles passed the specified inclusion and exclusion criteria. The article focuses on knowledge about IoT-Lora, energy saving needs, energy saving factors, and the paper demographics. The author synthesizes studies for that purpose on IoT applications using LoRa.

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1. INTRODUCTION

Lately, the internet has been overgrowing, including those that utilize the internet of things (IoT) technology in each country. Each has its own advantages and disadvantages. IoT must have a long battery life because it is essential. Due to high replacement costs for farmers because nodes are distributed over an extensive land area. Suppose the author looks at the latest technologies general packet radio service (GPRS), 3G, high-speed downlink packet access (HSDPA), high speed packet access (HSPA) and 5G). In that case, low-power wide area network (LPWAN) technology provides a breakthrough in old battery power, ensuring that the instrument is always active and maintains energy. One of them is long range (LoRa), and these new emerging technologies are widely used in various vital sectors. Although almost all of these technologies have low power, they still have weaknesses, such as signal requirements and good architecture [1].

LoRa was invented in 2012. This technology is compelling and has a comprehensive scope. The features of this technology allowed using the basics of modulation and managed by the LoRa Alliance, an organization consisting of more than 500 companies. In carrying out IoT communication, it cannot work alone. Usually, data transmission is carried out using the microcontroller antenna, but it cannot be done for remote IoT communication. LoRa components are needed to take over this role. As previously described, LoRa can transmit in wide-area technology that allows large areas to extend from one kilometer in urban until fifteen kilometers in rural environments [1].

These days, the world is in a state of having to provide billions of data estimated to be supported by all components of technology. The amount of data in the form of email, social media [2] and e-livestock system [3] require an adequate signal system; moreover, this data requirement affects the business [4]. While on component LoRa [5] and IoT device needs to improve energy savings, and maybe it should be very significant. Indeed, many types of IoT [6]. Many interconnected instruments transmitting and receiving large amounts of data include important information, always located in agricultural areas where the internet is unstable. Another issue is that several countries are planning to save energy or use clean energy to become the current topic of creating energy savings technology. Using energy-efficient components and methods to save energy is needed to generate energy savings. In some conditions, the battery may be used as a source of energy, but keep in mind that using a battery that has no energy creates a new issue in the form of waste.

One of the methods used for energy savings is to identify the components used. Because this study used IoT-LoRa devices, these two components need to be detailed so energy use is more efficient. In using IoT-LoRa, many elements can be maximized for energy savings. In IoT, several components can maximise savings on parts, namely the wireless sensor network (WSN) [7].

WSN, an essential component in IoT, has the largest component that requires energy consumption because there are many sensors and nodes. According to [8], carried out efficiency on the wireless network. study [9] do rechargeable, and study [10] performs a combination of energy harvesting and charging methods. LoRa research [11], sensing the battery with energy harvesting. Recently, many other things have been done by several researchers in energy saving.

Some components of IoT-Lora perhaps need energy savings, mainly focused on: unmanned aerial vehicle (UAV) [12], smart farming [13], [14], and image data transmission using LoRa [15]. Many studies have conducted surveys or reviews on LoRa and IoT but rarely discuss ways to save on both. With the condition of many smart devices, a way is needed to save energy on IoT [16] based on LoRa [17], [18]. With this review, it is hoped that it can help researchers to conduct savings experiments on this smart device. Another thing that can be used to do a review on IoT using LoRa is to look at some research that allows it to be an inspiration from other researchers.

Therefore, it is necessary to save energy on the components contained in the IoT using LoRa. Instead of conducting a regular review, they use the systematic literature review (SLR) method. While the review that will be made for energy savings can be maximized from the parameters on LoRa and IoT, from the other side, several methods can be done, such as harvesting, transfer, and conservation. Therefore, SLR concentrates on the latest study conducted in leading journals so that the research results displayed can be trusted. This review is expected to be a benchmark for saving other smart components in the future.

The author must follow several appropriate stages in good use of SLR, explained in stage 2. This is done to filter the research results relevant to the author's goals. After the screening results are successful and shown, the results will be displayed in section 3. After that, a discussion is carried out on the influence of the literature review. Last Section 4 will explain the conclusions in this study.

2. METHOD

In this study, the author proposed methodology used is SLR According to Kitchenham [19], [20]. The use of SLR will be very helpful for the author because the arrangement of the reviews is more regular. SLR is also used in this study for the author's goal. All SLR research methods use the previous patterns [21] and [22]. The following SLR steps are described in Figure 1.

2.1. Planning

2.1.1. Research question (RQ)

This stage is the Phase that underlies the SLR (see Figure 1) because the author must form a research question. The focus carried out on study focuses on IoT-LoRa energy savings. Some things that can be arranged in this study are:
RQ1: How to know knowledge about IoT, LoRa, and energy savings?
RQ2: Why does the use of IoT-LoRa need energy saving?
RQ3: What energy saving factors can affect IoT-LoRa?
RQ4: Where are the study demographics regarding IoT-LoRa energy saving from?

2.1.2. Data source

In this study, research papers were selected based only on instruments and capacities with look through diaries identified with energy savings, IoT and LoRa come from IEEE, ACM, MDPI, ScienceDirect, Springer, Hindawi and IAES.

2.1.3. Search string

Several possibilities can then be searched for words that have the same meaning as the definition Boolean "OR" and "AND" used to filter study lists from internet sources, such as ("LoRa" OR "LPWAN")

AND ("IoT" OR "internet of things") AND ("energy efficiency" OR "energy management" OR "energy savings").

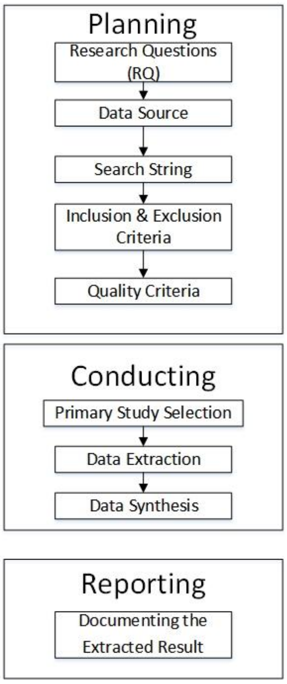

Figure 1. SLR for review IoT, LoRa, and energy savings [21]

2.1.4. Inclusion dan exclusion criteria

a. Inclusion

Studies that have been determined must be compiled using an international language, namely English and selected by determining the year from 2016 to 2021. The filtered study results discuss the development of Energy Savings, IoT, and LoRa.

b. Exclusion

Paper that does not have an overview of energy saving, IoT and LoRa.

2.1.5. Quality criteria

This section measures the quality used when the author has obtained the appropriate journal. This stage is carried out simultaneously after the previous process.

QA1= Original and study written in English
QA2= The study aims to investigate energy savings techniques, IoT and LoRa
QA3= Study aims to find a study that is very relevant based on content and references

2.2. Conducting

At the stage where the quality criteria have been determined for inclusion in the bibliography, the next part is to process the information in the form of data and build a synthesis. The author utilizes the tollgate approach suggested by Afzal *et al.* [23] and follow pattern [22], which consists of five phases:

First phase : collecting for all relevant articles
Second phase : inclusion and exclusion study based on abstract and title
Third phase : inclusion and exclusion study based on conclusions and introduction
Fourth phase : inclusion and exclusion study based on full text
Fifth phase : final selection for reporting full text

2.3. Reporting

2.3.1. Documenting the extraction result

At this stage, the extraction stage is carried out to see the originality and the classification of the review papers taken. Classification can be done based on the demographics of the paper review.

3. RESULTS AND DISCUSSION

According to the previous stage, the authors found 252 articles that passed the five screening processes, as listed in Table 1 of the number of search result articles from 2016 to 2021.

After getting 252 articles from different databases, several selections were made using the four phases according to subsection 2.2 and use database (see Table 1), as shown in Table 2.

Table 1. The origin of the article and the number of search results

Database	Result
IEEE	107
MDPI	55
ACM	43
Springer	23
ScienceDirect	12
Hindawi	10
IAES	2
Total	252

Table 2. Article selection

	First phase	Second phase	Third phase	Fourth phase	Fifth phase
Data in database	252	152	73	50	44

After selecting 44 suitable review articles were obtained for the last phase (see Table 2). This selected article became the reference for this Research.

The author will start with a paper on knowledge, savings needs, and energy saving factors on the focus of the study on IoT, LoRa, and several energy saving techniques, presented in Table 3. After knowing the distribution of papers according to Table 3, which resulted in 44 papers that became references. After that, according to subsection 2.3, the author conducted demographics of countries from these 44 papers, as shown in Table 4.

Table 3. IoT, LoRa, energy saving (knowledge, savings needs, and energy saving factors paper)

Focus study	Reference	Numbers of papers
IoT	[6], [7], [12]–[14], [16], [24]–[31], [32]–[36]	19
LoRa	[1], [5], [15], [17], [18], [37]–[40]	9
Energy savings techniques	[8]–[11],[41]–[49], [50]–[52]	16
Total		44

Table 4. Demographics of Countries

Country	Number of publication
China	7
USA	5
India	4
Turkey	3
France	3
Iran	3
South Korea	2
Greece	2
Germany	2
Indonesia	1
UK	1
Italy	1
Australia	1
Ghana	1
Iraq	1
Malaysia	1
Saudi Arabia	1
Pakistan	1
Mexico	1
Spain	1
Belgium	1
Colombia	1
Total	44

According to Table 4, the demographics of each country, countries in China and the USA, received a lot of articles about IoT-LoRa for energy saving, then discussed in India.

The previous study review only focuses on each part that affects energy savings on IoT using LoRa. But previously, the author found the energy needs of the essential components of IoT using LoRa. Several studies have measured how much energy is needed when a technician uses an IoT-LoRa, as shown in Table 5 is an example of the power consumption used in simple IoT-LoRa adoption in [37], [40].

Simple energy needs can be used as a reference [37], [40] (see Table 5). For example, a study using a battery with a capacity of 2200 mAh can only be used in 2 days (assuming the device is always on and the voltage requirement is less than 5V). Considering the estimated billions of data states using IoT-LoRa, this device consumes a huge amount of energy with continuous data retrieval intervals. Table 5 is a simple example of power consumption but cannot interpret the estimated energy consumption when this occurs. LoRa and IoT devices need to increase energy savings significantly. At the same time, few studies have been reviewed in detail about energy saving on IoT using LoRa. Referring to this reason, the next stage, the author makes several possibilities that can be used to do this, which will be explained in the next sub-chapter.

Table 5. IoT-LoRa energy consumption assumed

Components	Consumption (hour)
Microcontroller	24 mA
LoRa	36,4 mA
Sensor	10 mA
Total	70.4 mA

3.1. LoRa overview

Basically, as in the physical layer, LoRa uses the spread spectrum technique sponsored by the Semtech company [40]. LoRa is part of LPWAN technologies called low power [18], [37]. This technology is very suitable for rural areas or open field areas. LoRa work in unlicensed frequency is known as industrial, scientific and medical (ISM). References [1], [5], [17], [18] and image data transmission [15] like have talked about LoRa, but if faced with the transmission of billions of data, energy savings are needed, therefore energy saving aims to save the parameters contained in LoRa. In this subchapter, the author will formulate several arrangements to maximize energy consumption. Here the author will make some assumptions (see Table 6).

Table 6. Factors affecting energy consumption on LoRa

Parameter	Ref.
Transmission power	[38] and guidebook from [53]
Bandwidth (BW).	[39]
Carrier frequency (CF).	[38] and [39]
Coding rate (CR).	[38]
Spreading factor (SF).	[39]

As shown in Table 6, the effects of power like transmission power, CF, BW, CR and SF, according to the researchers, can be used to maximize energy consumption because of the nature of LoRa, which is already low-power but with billion data conditions, will affect its consumption (but reference [52] not included because it does not contain Research, only a guide book). The author focuses on this parameter because LoRa is a long-distance communication and a data bridge to the internet source. On the other hand, apart from knowing the performance of LoRa, to see how to do efficiency, the calculation of power usage related to LoRa performance is also carried out. The complete energy use is subject to the communication power and the time live. Such as Total Energy = Power x Time on Air. LoRa should have taken advantage of the ambient voltage 3.3V-5V. The length of time in the air also depends on the transmission power limit (BW, SF and CR) and how long the data will be sent.

3.2. IoT overview

Suppose LoRa is part of the communication. At the same time, IoT is a component for sensing and processing. IoT [6], [16], [24] utilization can be used on UAV [12], and smart farming [13], [14] all of them consume more energy and need energy saving. The author describes the scheme used in IoT so that the parameters can be known to maximize energy saving, the IoT paradigm is shown in Figure 2.

Figure 2 shows several things that can be done, such as the process, object, people section. But the most energy consumption is in the WSN [7], [25]. In billion data conditions, energy savings can be made using reduced data, but the effect on energy changes is not much. So the author, in this review, maximizes important parameters or components in IoT for energy savings [26]–[28].

In IoT, the author creates. Categories that can also be used to minimize power usage on the IoT will be discussed in Table 7.

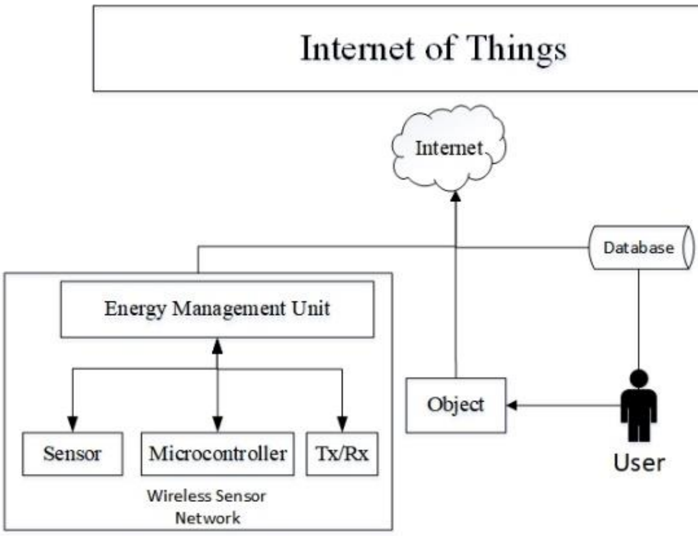

Figure 2. IoT energy saving concept

Table 7. Research focus for energy savings in IoT

References	Research Focus	Energy Savings Mechanism	Conclusion
[29]	Routing using a fuzzy neural network (ERFN)	Energy efficiency	ERFN improve efficiency
[30]	Energy efficiency policy	Policies	Rationale policy
[31]	Transmitting data	Energy balance	Reduce energy consumption
[32]	Monitoring system	Lowest power consumption	Improve (throughput/ power)
[33]	Data gathering	Optimizing energy consumption	Increase energy efficiency
[34]	Data collection	Energy utilization	Improve lifetime
[35]	Smart metering	Energy and consumption	Implemented a smart Metering
[36]	Smart phone	Prediction of energy	Energy behavior

According to Table 7, several Research focuses can maximize energy savings, especially in the network, data processing, and energy saving auxiliary devices in IoT. The author takes advantage of the results that are easy to apply to IoT, and at a later date, an experimental study can be carried out.

3.3. Schemes energy savings

Several factors affect IoT using LoRa. The author gets several energy savings schemes that can be applied, such as harvesting, transferring, and conservation energy. Figure 3 using in the study [41].

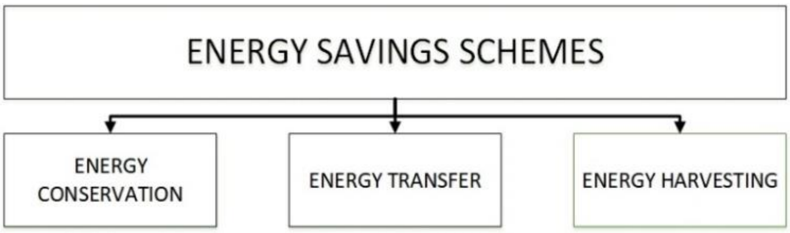

Figure 3. Energy savings schemes [41]

The author using [41] a scheme in Figure 3 because it can be applied for energy savings in Lora and IoT, for example, which has been used for efficiency papers [8], [9] where indeed the scheme for energy transfer is still complicated to implement. Here the author tries to review the energy savings technique that has been researched in Table 8.

In Table 8 the author reviews the Research on energy saving schemes that can be utilized in IoT using LoRa. But the easiest scheme to do is harvesting like Solar because energy sources can be taken from anywhere and the most difficult is to save energy using transfer. Review Table 7 allows researchers to look for other approaches to save energy.

Table 8. The other energy savings can be applied for IoT using LoRa

References	Research Focus	Energy Savings Mechanism	Conclusion
[42]	Network	Energy conservation	Optimization techniques
[43]	Sensor	Energy conservation	Best sensor selection
[44]	Ambient electric field	Energy harvesting	Self-configuring
[45]	Solar	Energy harvesting	WSN lifetime
[46]	Solar	Energy harvesting	Utilize MPPT
[10]	Solar	Energy harvesting	Charging solar and wireless
[11]	Energy-aware	Energy harvesting	Help Lorawan transmit data
[47]	Wind	Energy harvesting	Changing wind direction
[48]	Thermal	Energy harvesting	Enhance efficiency
[50]	Power loss shifted	Energy transfer	Design inductive Energy Transfer
[49]	Data transmission	Energy transfer	Transmission contactless
[51]	Time scheduling and transmission	Energy harvesting	Effectiveness
[52]	Electrical devices	Energy harvesting	Maximizing MPPT

4. CONCLUSIONS

Recently, IoT technology has dramatically increased the views of researchers and industry. The authors identify current research papers and offer insights related to IoT using LoRa SLR method is used in this study to find the initial meaning of IoT and LoRa, then find out why energy saving is needed, find important factors related to IoT-LoRa using energy savings and finally find out research demographics according to RQ on SLR. The author found 44 papers after using SLR that could answer RQ. The author is looking for articles from IEEE, ACM, MDPI, Springer, Hindawi, Science Direct, and IAES because they consider quality publishers and are by the author purpose of the review search. Energy savings are needed because it comes from searching for knowledge about IoT-LoRa. Therefore, the author knows what factors influence this. The author searched for papers on this knowledge that the required SLR review demographics were mostly China, the US, and India. The author found several methods on LoRa and IoT that can be stored. The author also finds that energy saving can be implemented using several techniques such as; transfer, harvesting, and conservation. The implementation of this technique can be used in both IoT and LoRa. The authors suggest that experiments can be carried out using energy savings techniques from this research review in the future. Finally, a review was also carried out involving drones for communication using LoRa.

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