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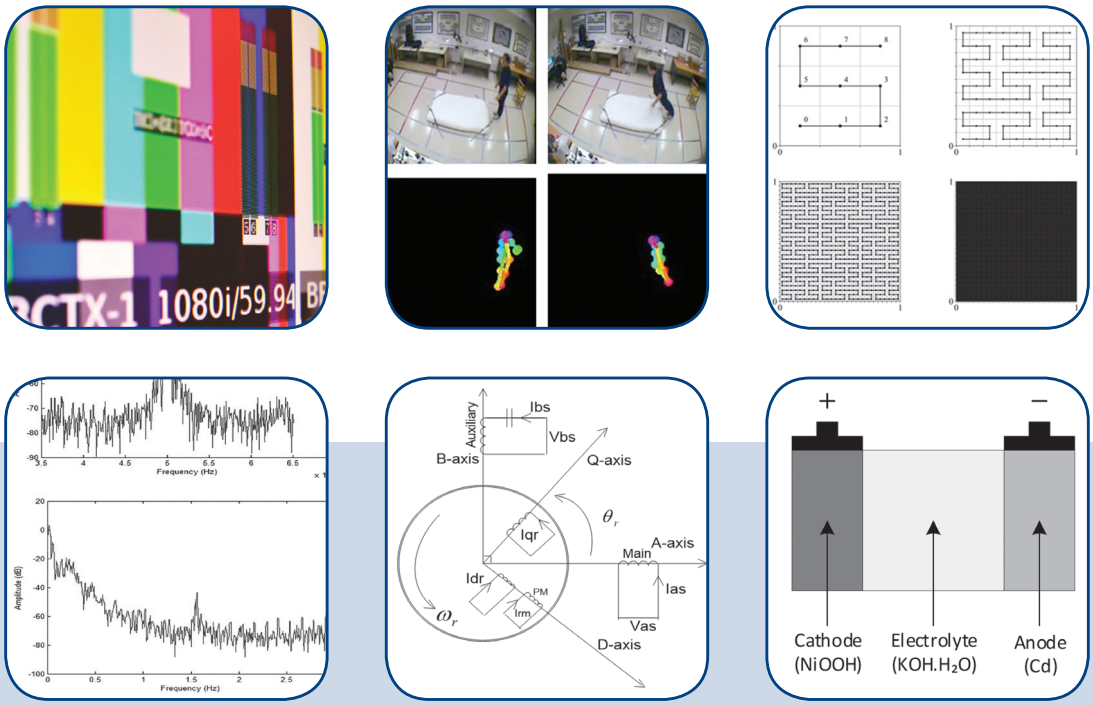

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Rules-Based System for Writing Arabic Numerals in Indonesian Words

Original Scientific Papers

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Abstract *– One of the algorithms stored in natural intelligence is the writing of Arabic numerals in Indonesian words. Algorithms in naturals intelligence are not easy to find. This problem gave us an idea to create artificial intelligence that tries to mimic natural intelligence algorithms. The proposed algorithm for building artificial intelligence is an R-Z rule-based system. This rule-based system contains a knowledge base of R-Z rules and a knowledge base of facts. In the knowledge base, the R-Z rule provides the R rule and the Z rule, while the facts knowledge base provides facts in the form of a definite standard number and an affix word. R-Z rule-based system for reasoning writing Arabic numerals in Indonesian words uses forward chaining. Artificial intelligence designs that mimic naturals intelligence in writing numbers in Indonesian words were made in C using Borland C++ 5.02 software. The experimental results show that by applying the R's rule of seven rules and Z's of twenty-five rules, the R-Z rule-based system can write Arabic numerals in Indonesian words from Arabic numerals "0" to Arabic numerals "9999999". For example, to write the Arabic number "10" in Indonesian words, the R-Z rule-based system starts with the R2 rule. Rule R2 takes action on Z3 to create new facts about Arabic numerals in the Indonesian word, namely "SEPULUH."*

Keywords*: natural intelligence, artificial intelligence, rules-based system, Borland C++ 5.02*

1. INTRODUCTION

When humans are born into the world, the learning process in humans has started. The human brain, also known as natural intelligence, then stores all the information it gets. Apart from being in the form of sound, one of the outputs of naturals intelligence is hand gestures in writing Arabic numerals in Indonesian words.

Arabic numerals without the cents after a comma [1] are Arabic numerals written in Indonesian words. We realize that natural intelligence has the potential to make mistakes in writing Arabic numerals in Indonesian words. Therefore, how to write the number of numerals, letters and the correctness of writing Arabic numerals in Indonesian word in the letter of payment need to be checked [2]. For example, single Arabic numerals, such as "1" [3] in Indonesian words, are "SATU." In compound Arabic numerals, such as "111" [3], the write-in Indonesian words are "SERATUS SEBELAS."

Rule-based systems (also known as production systems or expert systems) are a method that can use to create simple artificial intelligence [4-9]. Based on the above opinion, we were inspired to actualize artificial intelligence that could imitate natural intelligence in writing Arabic numerals without the cents after a comma in Indonesian words.

The artificial intelligence that we create is artificial intelligence-based on our ability to communicate using the C language with computers. The language we use to communicate with computers is the simple C language. The goal is for the computer to do its job the way we want it.

In this paper, C is the language we use to communicate with computers in making artificial intelligence. In addition, we have designed the C language syntax in artificial intelligence to be as simple as possible and easy to understand for ourselves and the computer.

In making artificial intelligence, the information (also known as facts) that we use is atomic facts of Arabic numerals in Indonesian words. The knowledge base of factual is a place to store all atomic Arabic numerals words in Indonesian words. Therefore, to obtain atomics data for Arabic numeric words in Indonesian words, we applied a reasoning method, namely forward chaining reasoning. As for the control, we apply rule-based methods. Furthermore, the rules we use are supervised rules (to get atomic number words in Indonesian words, we do not adjust the search technique).

We hope that this artificial intelligence can be an alternative solution to errors that may occur by natural intelligence in writing Arabic numerals without the cents after a comma in Indonesian words.

2. LITERATURE REVIEW

There have been many researchers who have implemented a rule-based system in making artificial intelligence. Each artificial intelligence has its specialty and depends on the problems it solves.

Application of rule-based systems for manufacturing artificial intelligence that provides good results such as prevention and early detection of breast cancer [7], diagnosis of chest pain in infants and children [8], diagnosis and appropriate advice on onion plant diseases [9], and others [4-6].

Rule-based systems are in place to create artificial intelligence that provides good results such as prevention and early detection of breast cancer [7], diagnosis of chest pain in infants and children [8], diagnosis and appropriate advice on onion plant diseases [9], and others [4-6].

2.1 RULES-BASED REPRESENTATION FRAMEWORK

Rules represent most of the knowledge in a rule-based system. That is a conditional sentence that connects one statement of fact with another [10]. In [10] also explains that the representation of factual in the database can use a convenient pattern. Patterns are like arrays, string symbols, or list structures. The rules are

IF (condition) THEN (action)

As the name implies, a rule-based system uses rules to select an action. In general, the condition part or the left side of the rules can be any pattern. This pattern is part of the matching to the database. Usually, it is also allowed to contain variables that may be bound in different ways. Then the actions section or the right side of the rule can be executed.

It is also explained by [10] that rule interpreters have the task decide which rules will be applied. It decides how to determine the condition rule that must be compatible with the database and monitors the problem-solving process. When implementing an interactive program, it can turn to the user and ask for information (facts) that allows for rule implementation.

2.2 RULES-BASED DEVELOPED REPRESENTATION FRAMEWORK

The rule-based system developed (we call the R-Z rule-based system) to be applied in this paper, namely writing Arabic numerals with Indonesian words the same as the rule-based system in general. The rules are:

First rule:

IF (condition-1) THEN (function)

The condition-1 part or the left side of the rule in the first rule must be an integer value variable. This variable is part of the matching to the appropriate integer value. Then the function section or the right side of the rule can execute

Second rule:

IF (condition-2) THEN (new_fact) AND (function)

The condition-2 part or the left side of the rule in the second rule must be an integer value variable. This variable is part of the matching to the appropriate integer value. Then in the new_facts section and the function or the right side of the rule can be executed.

Third rule:

IF (condition-3) THEN (new_ fact)

The condition-3 part or the left side of the rule in the third rule must be an integer value variable. This variable is part of the matching to the appropriate integer value. Then in the new_facts section or the right side of the rules can be executed.

Notation Rules

Because the rule-based system applied in this paper has several rules, it is necessary to create a rule notation. This rule notation aims to facilitate the observation of the reasoning carried out by this rule-based system. The notation is:

- The first rule is denoted as rule R.
- The second and third rules are denoted as rule Z.

Rules Diagram

The rule diagramming in this paper aims to describe a rule-based system using rules to select an action. The diagram is:

- The first and second rules have the diagram form following:

Fig. 1. The first and second rules, where i>j

Fig. 2. The first and third rule

The rule diagram in Fig. 2 is a block diagram that produces new facts and recent facts as problem-solving.

2.1 BASIC STRUCTURE OF A RULE-BASED SYSTEM

2.3.1 Knowledge Base

The knowledge base contains domain knowledge that is useful for problem-solving. In a rule-based system, the knowledge base represents a set of rules. Each rule can have a relation, recommendation, direction, strategy, or heuristic and has an IF (condition) THEN (action) structure, where when the condition part of the rule fulfills, the actions part will be carried out [11].

2.3.2 Database

The database includes a set of facts. These facts will come out whenever they match the IF (condition) part of the rules stored in the knowledge base [11].

2.3.3 Inference Engine

The task of the inference engine is to interpret and evaluate facts in the knowledge base to provide answers. Pada makalah ini, mesin inferensi menerapkan aturan R dan Z (dijelaskan pada bagian 2.2) dari basis pengetahuan dan mengevaluasi untuk mendapatkan fakta baru. Proses evaluasi dilakukan berulang-ulang bilamana penafsiran menemukan aturan R. The evaluation ends when you get rule Z as the answer. In applying the R and Z rules, the inference engine works by forward chaining.

2.3.4 User Interface

The user interface is a place to communicate between users with artificial intelligence. The user interface is made up as simple as possible and user-friendly. The available user interfaces are as follows:

- A place to enter Arabic numerals without decimal places.
- Information. Want to try again? Option [YES / NO.]

2.2 ARABIC NUMERALS

Arabic numerals are symbols that represent quantity. The number of digits in the international standard is an Arabic number in multiples of ten. Often the number system is also referred to as Arabic numerals because it takes numerals from the Arabic numeral system and symbols [12-16].

Arabic numerals consist of ten basic symbols as follows [17-19]:

0, 1, 2, 3, 4, 5, 6, 7, 8 and 9

The single Arabic numeral symbol is also called a number. A combination of two or more of the ten basic Arabic numerals is called compound Arabic numerals.

Fig. 3. Arabic numerals 153

2.5 POSITION SEQUENCE OF ARABIC NUMERALS

The reading of Arabic numerals is read based on the sequence of digit positions. The read position starts from the right end and moves to the far left. In the number system, each position occupied by an Arabic number (also called a digit), either a single or a combination, has a meaning. The meaning of an Arabic number in a word in Indonesian follows its location (for three positions), as follows:

- The unit is the first digit from the far right.
- Tens are the second digit from the far right.
- Hundreds are the third digit from the far right.

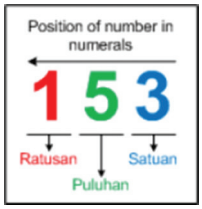

Fig. 4. The meaning of Arabic numerals positions in Indonesian words

Fig. 4 explains that "153" is a combination of the following three Arabic numerals "1", "5", and "3". Based on the position order, the single Arabic number "1" is HUNDREDS, then the single Arabic number "5" is TENS, and the last single Arabic number "3" is UNIT.

2.6 WRITING ARABIC NUMERALS IN INDONESIAN WORDS

In Indonesian grammar, writing Arabic numerals in Indonesian words is one of the learning topics [20-21]. Learning to write Arabic numerals in Indonesian words becomes useful when making transactions such as deposits/transfers/clearing/billing, in banks, or in receiving money.

A transaction will be accepted if the check between writing Arabic numerals and writing Arabic numerals in Indonesian words both of the same meaning is correct [2]. The following is an example of a transaction at a bank where the Arabic numeric writing and Arabic numeric writing in the Indonesian word entered in the deposit/transfer/clearing/billing form have the same meaning.

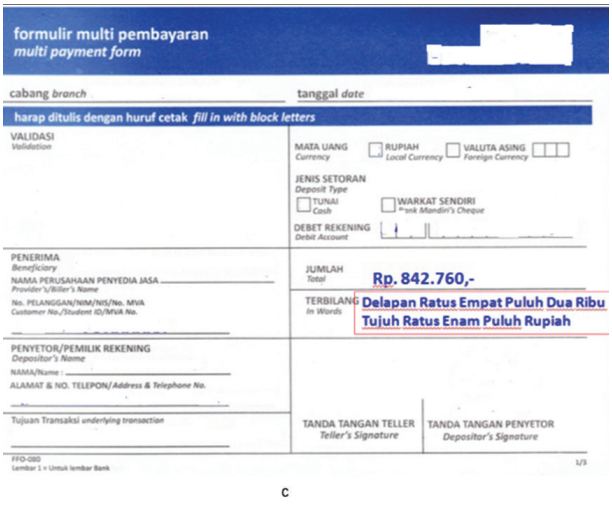

Fig. 5. multi-payment form

Fig. 5 explains that the multi-payment form must write Arabic numerals symbols accompanied by Arabic numeral writing in Indonesian words.

Writing Arabic numerals without the cents after a comma in Indonesian words is a single and combined type sequentially shown in Table 1 and Table 2.

Table 1. Single Arabic numerals

Arabic Numerals	The number of digits	Arabic Numerals In Indonesian words
0	1	NOL
1	1	SATU
2	1	DUA
3	1	TIGA
4	1	EMPAT
5	1	LIMA
6	1	ENAM
7	1	TUJUH
8	1	DELAPAN
9	1	SEMBILAN

Table 2. Combined Arabic numerals

Arabic Numerals	The number of digits	Arabic Numerals In Indonesian words
10	2	SEPULUH
11	2	SEBELAS
12	2	DUA BELAS
20	2	DUA PULUH
100	3	SERATUS
191	3	SERATUS SEMBILAN PULUH SATU
210	3	DUA RATUS SEPULUH
311	3	TIGA RATUS SEBELAS
412	3	EMPAT RATUS DUA BELAS
1000	4	SERIBU SATU
2010	4	DUA RIBU SEPULUH
3011	4	TIGA RIBU SEBELAS
10000	5	SEPULUH RIBU
20010	5	DUA PULUH RIBU SEPULUH
30011	5	TIGA PULUH RIBU SEBELAS
40012	5	EMPAT PULUH RIBU DUA BELAS

3. RESEARCH METHODOLOGY

3.1 EXPERIMENTAL ENVIRONMENT

In this paper, the C language in Borland C++ 5.02 software is a device that we use to communicate with computers to create artificial intelligence that mimics the ability of natural intelligence to write Arabic numerals in Indonesian words. For the operating system, we use Microsoft Windows 8.1 Pro-64 bit using the following platform: Intel (R) Core (TM) i3 3217U CPU @ 1.80 GHz and Memory (RAM): 2.00 GB.

3.2 RULES-BASED SYSTEM DESIGN FOR WRITING ARABIC NUMERALS IN INDONESIAN WORDS

The design of artificial intelligence applies a rule-based system for writing Arabic numerals without the cents after a comma in Indonesian words, as shown in Fig. 6.

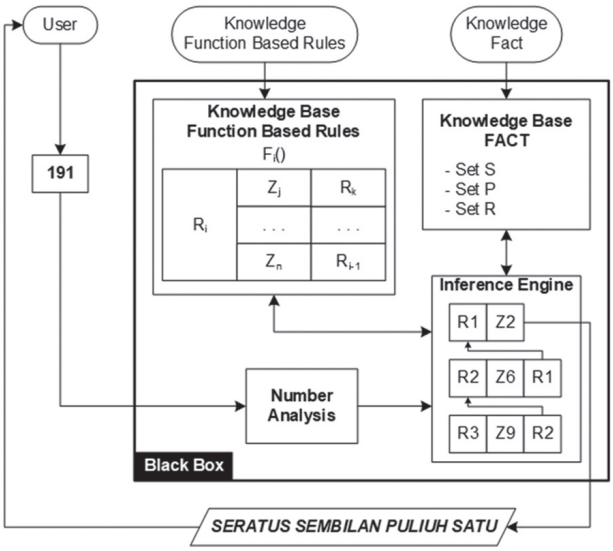

Fig. 6. Design of a rule-based system for artificial intelligence to write Arabic numerals in Indonesian words

Fig. 6. explains that in designing artificial intelligence so that it can write Arabic numerals in Indonesian words using a rule-based system, it has a supporting component. The components that make up this artificial intelligence unit are as follows:

1. User interface. This component functions as a place for communication between users with artificial intelligence, such as entering Arabic numerals without the cents after a comma or leaving artificial intelligence.
2. Knowledge base rules. This component stores a set of rules for problem-solving.
3. Knowledge base of facts. This component stores a set of facts to form a new datum.
4. Inference engine. This component is to interpret and evaluate facts in the knowledge base to provide answers.
5. Add rules. This component is for adding new rules.
6. Add facts. This component is to add a new datum.

3.3 Rule-Based Algorithm for Writing Arabic Numerals in Indonesian Word

The algorithm of artificial intelligence for writing Arabic numerals without the cent after a comma in Indonesian words using a rule-based system is as follows:

Step 1: Creating the user interface.

The user interface used for:

4.1 Enter the Arabic numerals of the user.

4.2 Interact with computers.

a. If the user enters non-Arabic numerals, the system notifies the error, then the system exits.

b. If the user enters Arabic numerals without the cents after a comma, the system performs the reasoning. If the system resolves the problem, the user interface displays Arabic numerals in Indonesian words. If the system cannot solve the problem, it gives the user the option to type "Y/ N." If the user types "N," the system exits.

Step 2: Creating a database.

The database contains a collection of facts in the form of atomic Arabic numerals in Indonesian words. Examples of atomic Arabic numerals in Indonesian words are as follows:

Set S = {Nol, Satu, Dua, Tiga, Empat, Lima, Enam, Tujuh, Delapan, Sembilan}

Step 3: Create a knowledge base

The rules we created are the R and Z rules. The R and Z rules in the knowledge base, as shown in the diagram, are as follows:

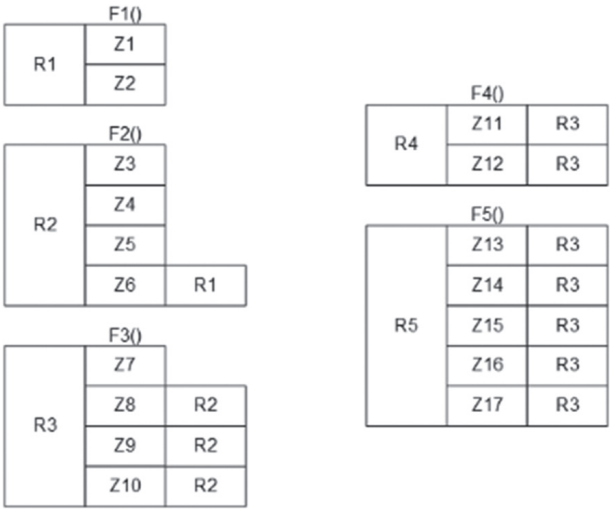

Fig. 7. Function-based rules (R-Z) in the knowledge base of artificial intelligence write Arabic numerals in Indonesian words

Step 4: Create Output Views

This section has the task of displaying the results of the reasoning that occurs in the inference engine. The reasoning results views are the R and Z rules.

For example (see fig. 6 in the inference engine box). Writing Arabic numerals in Indonesian words in Arabic numerals 191 uses the R3 Z9 R2 Z6 R1 Z2 reasoning, and Arabic numerals without decimal places are "SERATUS SEMBILAN PULUH SATU."

4. RESULTS

This section will explain the result of test a rule-based algorithm for writing Arabic numerals without the cents after a comma in Indonesian words. The algorithm testing carried out using two types of test input. The two types of test input are as follows:

1. Enter not Arabic-numerals type.
2. Enter the Arabic-numerals type.

4.1 ENTER NOT ARABIC-NUMERALS TYPE

In addition to numerals representing the ASCII code between 48 and 57, input is not Arabic numerals. This test aims to find out that the R-Z rule-based system has worked consistently as in the design.

In this section, using two types of input, the first is the type of letter, and the second is the type of combination between numerals with comma punctuation.

4.1.1 Test input with letters

In this test, the letter "a" is the letter chosen as the input for the system. When typed the letter "a" the system responds, as shown in Fig. 8.

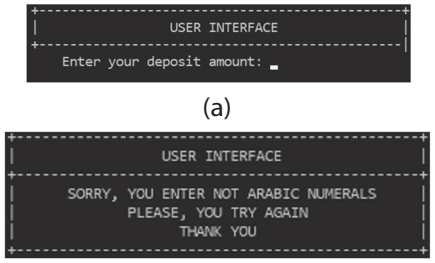

Fig. 8. (a) The letter "a" as input, (b) the response of artificial intelligence using an R-Z rule-based system

4.1.2 Test input by combining Arabic numerals with comma punctuation.

In this test, the combination of Arabic numerals with a comma punctuation "123," is the input for the system. When the Arabic number "123" is typed, the system does not respond. However, the system response is as shown in Fig. 9 after typing a comma.

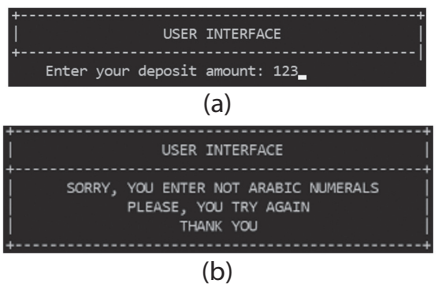

Fig. 9. (a) Combined Arabic numerals with a comma punctuation "123," as input, (b) responses from artificial intelligence using an R-Z rule-based system

The test results above show that the rule-based algorithm for writing Arabic numerals without the cents after a comma in Indonesian words has worked according to the design. In other words, the system will not write Arabic numerals in Indonesian words with such input.

4.2 ENTER WITH ARABIC NUMERALS WITHOUT THE CENTS AFTER A COMMA

In this section, the rule-based algorithm for writing Arabic numerals without the cents after the comma in Indonesian words will be tested with Arabic numerals without the cents after the comma in singular and combined form.

Since the draft states that new rules and facts can be added to the system, the system test by entering Arabic numerals without the cents after the comma carry out into two parts as follows:

1. Before adding new rules and facts.
2. After adding new rules and facts.

4.2.1 Testing the system before adding new rules and facts

In this section, enter the Arabic numerals without the cents after the comma in the singular and combined form used to test the system, as shown in Table 3.

Table 3. Data Single and Combined Arabic Numerals for Testing the R-Z Rules-Based System

Arabic Numerals	The number of digits	Arabic Numerals In Indonesian words
0	1	NOL
1	1	SATU
10	2	SEPULUH
11	2	SEBELAS
12	2	DUA BELAS
120	3	SERATUS DUA PULUH
121	3	SERATUS DUA PULUH SATU
122	3	SERATUS DUA PULUH DUA
2345	4	DUA RIBU TIGA RATUS EMPAT PULUH LIMA
42760	5	EMPAT PULUH DUA RIBU TUJUH RATUS ENAM PULUH

The results of the rule-based algorithm test for writing Arabic numerals without the cents after the comma in Indonesian words use single and combined Arabic numerals in Table 3 as shown in Table 4.

Table 4. Test Results Single and Combined Arabic Numerals in the R-Z Rules-Based System

Arabic Numerals	Output from the System	Result
0	USER INTERFACE Your deposit amount: 0 Arabic Numerals in Indonesian Words // NOL //	Correctly
1	USER INTERFACE Your deposit amount: 1 Arabic Numerals in Indonesian Words // SATU //	Correctly
10	USER INTERFACE Your deposit amount: 10 Arabic Numerals in Indonesian Words // SEPULUH //	Correctly
11	USER INTERFACE Your deposit amount: 11 Arabic Numerals in Indonesian Words // SEBELAS //	Correctly
12	USER INTERFACE Your deposit amount: 12 Arabic Numerals in Indonesian Words // DUA BELAS //	Correctly
120	USER INTERFACE Your deposit amount: 120 Arabic Numerals in Indonesian Words // SERATUS DUA PULUH //	Correctly
121	USER INTERFACE Your deposit amount: 121 Arabic Numerals in Indonesian Words // SERATUS DUA PULUH SATU //	Correctly
122	USER INTERFACE Your deposit amount: 122 Arabic Numerals in Indonesian Words // SERATUS DUA PULUH DUA //	Correctly
2345	USER INTERFACE Your deposit amount: 2.345 Arabic Numerals in Indonesian Words // DUA RIBU TIGA RATUS EMPAT PULUH LIMA //	Correctly
42760	USER INTERFACE Your deposit amount: 42.760 Arabic Numerals in Indonesian Words // EMPAT PULUH DUA RIBU TUJUH RATUS ENAM PULUH //	Correctly

Table 4 explains that the rule-based algorithm for writing Arabic numerals without the cent after a comma in Indonesian words has worked according to the design. From the system output in table 4, we can state that this rules-based algorithm can write Arabic numerals in Indonesian words correctly.

4.2.2 Testing the system after adding new rules and facts

This section will test the algorithm for writing Arabic numerals without the cent after comma by adding some new rules and datums to the R-Z rules-based system. The new rules added are R6 and R7, as shown in Fig. 10.

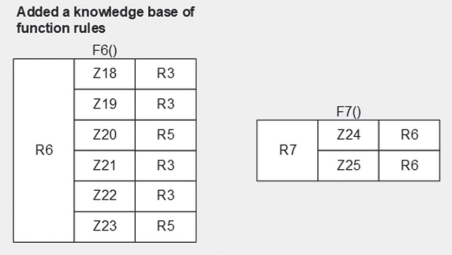

Fig. 10. New rules R6 and R7 added to the R-Z rules-based system

While the data used to test the new rules added to the R-Z rule-based system are the R6 and R7 rules, as shown in Table 5.

Table 5. Test Data for New Rules R6 and R7

Arabic Numerals	The number of digits	Arabic Numerals In Indonesian words
842760	6	DELAPAN RATUS EMPAT PULUH DUA RIBU TUJUH RATUS ENAM PULUH
999999	6	SEMBILAN RATUS SEMBILAN PULUH SEMBILAN RIBU SEMBILAN RATUS SEMBILAN PULUH SEMBILAN
9842761	7	SEMBILAN JUTA DELAPAN RATUS EMPAT PULUH DUA RIBU TUJUH RATUS ENAM PULUH SATU
9999999	7	SEMBILAN JUTA SEMBILAN RATUS SEMBILAN PULUH SEMBILAN RIBU SEMBILAN RATUS SEMBILAN PULUH SEMBILAN
10000000	8	SEPULUH JUTA

The results of the rule-based algorithm test for writing Arabic numerals without the cents after the comma in Indonesian words after adding the new rules R6 and R7 to the system with the combined Arabic numeric test data are in Table 5, such as shown in Table 6.

Table 6. Test Results for Combined Arabic Numbers in the New Rules R6 and R7

Arabic Numerals	Output from the System	Result
842760	USER INTERFACE Your deposit amount: 842.760 Arabic Numerals in Indonesian Words // DELAPAN RATUS EMPAT PULUH DUA RIBU TUJUH RATUS ENAM PULUH //	Correctly
999999	USER INTERFACE Your deposit amount: 999.999 Arabic Numerals in Indonesian Words // SEMBILAN RATUS SEMBILAN PULUH SEMBILAN RIBU SEMBILAN RATUS SEMBILAN PULUH SEMBILAN //	Correctly
9842761	USER INTERFACE Your deposit amount: 9.842.761 Arabic Numerals in Indonesian Words // SEMBILAN JUTA DELAPAN RATUS EMPAT PULUH DUA RIBU TUJUH RATUS ENAM PULUH SATU //	Correctly
9999999	USER INTERFACE Your deposit amount: 9.999.999 Arabic Numerals in Indonesian Words // SEMBILAN JUTA SEMBILAN RATUS SEMBILAN PULUH SEMBILAN RIBU SEMBILAN RATUS SEMBILAN PULUH SEMBILAN //	Correctly
10000000	USER INTERFACE SORRY, I CAN'T WRITE THAT ARABIC NUMERALS I HAVE NOT LEARNED YET PLEASE TEACH ME THANK YOU	Incorrect

5. DISCUSSION

The R-Z rule-based system that applies forward chaining as reasoning can create artificial intelligence for writing Arabic numerals without the cent after a comma in Indonesian words.

This artificial intelligence can carry out assignments writing Arabic numbers without the cents after the comma in Indonesian words are given by the user correctly at 93.3%. The rest, which is 6.7%, is incorrect.

Enter with combined Arabic numerals, namely "1000000," cannot be written in Indonesian words by this artificial intelligence. It's because artificial intelligence has not yet learned about the combined Arabic numerals. This error is not an absolute error because an algorithm always gives right or wrong answers, and both the answers are all correct [22].

However, a simple artificial intelligence that implements the RZ rule-based system can write Arabic numerals without the cents after the comma in Indonesian words from the Arabic numerals symbols "0" to "99999", only applies the R rule of five and the Z rule of 17 before adding the rules in the system. With the added knowledge of R6 and R7 with many Z rules of 25 rules, the Arabic numerals symbol that can be written in Indonesian words by artificial intelligence is "9999999."

In interpreting and evaluating the facts in the knowledge base to provide Arabic numeric writing without the cent after a comma in Indonesian words, the inference engine uses the R-Z rules. The R-Z rules used in interpreting and evaluating facts in the knowledge base by the inference engine are as shown in table 7.

Table 7. Results of Inference Engine Reasoning on Test Arabic Numerals

No Test	Arabic Numerals	Results of the R-Z Rule in the Inference Engine
1	0	R1 Z1
2	1	R1 Z2
3	10	R2 Z3
4	11	R2 Z4
5	12	R2 Z5
6	120	R3 Z9 R2 Z6 R1

No Test	Arabic Numerals	Results of the R-Z Rule in the Inference Engine
7	121	R3 Z9 R2 Z6 R1 Z2
8	122	R3 Z9 R2 Z6 R1 Z2
9	2345	R4 Z12 R3 Z10 R2 Z6 R1 Z2
10	42760	R5 Z17 R3 Z10 R2 Z6 R1
11	842760	R6 Z23 R5 Z17 R3 Z10 R2 Z6 R1
12	999999	R6 Z23 R5 Z17 R3 Z10 R2 Z6 R1 Z2
13	9842761	R7 Z25 R6 Z23 R5 Z17 R3 Z10 R2 Z6 R1 Z2
14	9999999	R7 Z25 R6 Z23 R5 Z17 R3 Z10 R2 Z6 R1 Z2
15	10000000	Rules not found

Table 7 explains artificial intelligence begins to write Arabic numbers without the cents after the comma in Indonesian words when the inference engine has rules such as Z1, Z2, Z3, Z4, Z5, or Z6.

6. CONCLUSION

The experimental results show that a rule-based system can be applied to create artificial intelligence that mimics the ability of natural intelligence in writing Arabic numerals in Indonesian words.

Writing Arabic numerals in Indonesian words that artificial intelligence can do is still limited, starting from the single Arabic numerals "0" to the combined Arabic numerals "9999999".

This artificial intelligence will ask to get additional new knowledge when it meets Arabic numerals entered from an unknown user. The addition of rules and facts to artificial intelligence will increase the number of written Arabic numerals in Indonesian words.

Although it can imitate natural intelligence in writing Arabic numerals in Indonesian words, this artificial intelligence is not yet applicable in general. Because in the number system, there is an arrangement of Arabic numerals with Arabic numerals after the comma. Because there is an arrangement of Arabic numerals that applies in the number system, this artificial intelligence has not yet handled it.

Therefore, this simple artificial intelligence still needs to be developed to suit the existing number system in general.

7. ACKNOWLEDGEMENT

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Evaluation of Data Mining Techniques and Its Fusion with IoT Enabled Smart Technologies for Effective Prediction of Available Parking Space

Original Scientific Paper

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Abstract *– After experiencing the hard times of pandemic situations we learned that if we could have a smart system that can help us in automatic parking of the vehicles then it could be a great help to society. This idea motivated us to carry out this current work. Though, nowadays, in almost every application domain, IoT techniques are the buzzword. IoT techniques can also be used to achieve efficacy in predicting free available parking space in advance. But the biggest challenge with IoT techniques is that they generate numerous data, which makes its analysis intangible. It was realized that if IoT techniques can be fused with outperforming data mining techniques, more efficient predictions can be performed. Thus, for this purpose, the main objective of our paper is to firstly, select the most appropriate data mining technique, based on performance evaluation, and then to perform prediction of available parking space in advance by fusing it with IoT techniques. Due to the busy schedule, the drivers need to get information about free parking spaces in advance by using smart phones. With the help of this information, it will be easy for the drivers to park their vehicle in the exact location without wasting their precious time and will maintain social distancing in crowded areas too. Data mining techniques can play an important role in the prediction of available parking space, by extracting only relevant and important information when applied to the given dataset. For this purpose, a comparative analysis of five data mining techniques such as the Support Vector Machine, K- Nearest approach, Decision Tree, Random Forest, and Ensemble learning approaches are applied on PK lot data set by using Python language. For calculation of result anaconda (spyder) is used as a supportive tool. The main outcome of the paper is to find the technique that will give better results for the prediction of the available space and if we fused data mining techniques with IoT technologies results are improvised. Evaluation parameters that are used for finding the best technique are precision, recall, accuracy, and F1-Score. For numerical calculation of the results, the k-fold cross-validation method is used. As the empirical results are calculated using the Pk lot dataset, the decision tree outperformed the best among all the techniques that are selected for analysis.*

Keywords*: IoT-Enabled Smart Parking, Parking Sensors, Data Mining, Ensemble Learning, and Decision Tree*

1. INTRODUCTION

The number of vehicles on the streets of metropolitan cities and large urban areas has grown tremendously. It is also difficult to track down empty parking spaces due to such an enormous number of vehicles. Therefore, drivers also waste energy in searching for a parking space, which results in additional traffic. In metropolitan cities like Delhi, Bombay, or even in smaller cities like Rohtak most challenging task associated is to find the free parking space in public areas. One of the survey reports of IBM [15] states that about 45% of the road traffic in cities is due to drivers searching for the vacant parking space for parking their vehicles. Due to vehicles, many problems intensify such as pollution emission, consumption of fuel, congestion on roads, wastage of time, and also contributing to the accidents because of the focus of the drivers for finding free parking[1]. In near future, it is estimated, that there will be around 2 billion cars on the road. With the rapid growth of the vehicles in a small amount of time congestion increase with the passage of time and it is difficult for drivers to find the parking area .Lots of work have been done for the management of parking space such as the utilization of sensors that determines

vacant parking spots[2] and feedback by the users that will help the drivers to inform about other vacant space by a mean of smart applications that will identify the vacant parking space[3] .These systems are based upon the temporary data, so there is less probability for reserving and allocating the free parking space, so these techniques are practical in a short frame where the driver is in a nearby location of the parking space. These techniques don't assure if a parking space is available or not. At a particular point in time in the near future to predict the accessibility of vacant parking spaces these techniques are combined with artificial intelligence approaches that provide the smart solutions in the real environment. To obtain better results for the prediction of vacant space, a lot of data is generated by IoT sensors that are further coupled with other IoT devices, and data mining techniques are applied to the real-time sensor data to get hidden patterns from available data and it will provide the useful information to the drivers. IoT devices can produce a large volume of data and that data is locally processed and transferred to a centralized database, where it can be further processed and analyzed to produce knowledge. Data mining is defined as a family of techniques for analyzing such huge data that will collect the historical data which is generated by IoT devices and will preprocess the data to find the hidden patterns that will help in predictive analysis. Data mining is a strong contributor to deal with the huge amount of data that is generated from IoT devices. That is the reason why we fused data mining techniques with IoT devices that generate a tremendous amount of data. A large number of data mining techniques are available, one of the problems arise is to detect the appropriate data mining technique for the given problem and the size of the records i.e dataset because the performance analysis of each data mining model varies from problem to problem that is done for comparing data mining algorithms in numerous application domains. Data mining algorithms have been compared for different applications such as Djaneye-Boundjou et al.[4] applied K-Nearest Neighbor (KNN), Support Vector Machine (SVM), and Artificial Neural Network (ANN) methods to a malware sorting problem and find the solution in terms of accuracy and KNN outperformed SVM and ANN.

1.1 DESCRIPTION

The main objective of the paper is to find the optimized technique that will help the drivers for the prediction of free parking space based on the data that is generated by IoT sensors. When working with IoT sensors the biggest challenge is the size of the data generated by IoT devices. To deal with this challenge, we have fused data mining techniques that will handle large data efficiently. In this paper, we are analyzing different data mining techniques that can help us to regulate the best predictive technique among them for the accessibility of the free parking space. The PK lot dataset is used for the analysis of the results. For comparative analysis, we choose different data mining techniques such as the K-Nearest approach, Ensemble Learning approach, and decision Tree approach, Support Vector Machine, and Random Forest. Even though the number of data mining techniques are available in the literature, we choose these five data mining techniques because these are widely used by renowned researchers. At the end of the paper, the result is quoted with perspective to the main objective that to find the optimized technique for the prediction of vacant parking spaces.

- Identification of best performing algorithm among best known and widely used data mining algorithms.
- Endorsement of top-k free parking areas with admiration to the remoteness between the present location of the vehicle and vacant parking space.
- To determine how suitable prediction of available parking space is applied to the PK lot dataset

Impression of our Parking Space Prediction Model on Smart World. Now the day's widely used term is the smart world, it is an umbrella that will quarter numerous traits associated with urban research. Related to smart cities most important branch are transportation and flexibility. Smart flexibility and transportation have the latent that will make the important involvement in smart cities that will utilize IoT techniques. Traffic congestion problem occurs due to driver search for a parking place that will affect numerous procedures and fields of the smart cities some of these domains are parking space management, traffic management, and route planning management [15]. IoT-enabled smart parking system marks an effort that will diminish traffic jamming [7] that is presented by parking prediction data mining model that will make a significant impression on the smart world.

1.2 ORGANIZATION

The paper is organized as follows. In section 2 literature survey is presented. In Section 3 we will present a block diagram of IoT-Enabled smart parking system. In section 4 we will present an overview of the five data mining techniques that are used for analysis. In section 5 the performance of these data mining techniques is represented using evaluation parameters in which we will represent the result using precision, recall, accuracy, and F1-score, and finally conclusion is presented in section 6.

2. RELATED WORK

To deal with the parking spot reference problem, several systems have been proposed. A reference system based on real-time sensors is the most common solution to the problem that can detect the accessibility of the

parking space[2] . Wireless Sensor network is a real-time evaluation that is connected to a web server for gathering information that will decide the available parking space by J.Yang et al.[5] . The information is transmitted to the users via a cell phone. Another solution is proposed by Dong et al.[6] . Dong proposed a virtual reality-centered technique that will compact with factual time recognition of the free parking spaces. These systems gather the public information of free parking space. For example rented space, available space, price, etc all these types of information are collected by simulation-based methods after collection the public information is sorted using page rank algorithms. This algorithm is centered on examine actual data so they are not capable to handle the probability to forecast the accessibility of the parking space in the time frame (eg between 15 and 35 minutes from the present time) within the interest of the demand of the users. One solution is proposed by R.E Barone et al.[7] . An architecture is proposed by him and it is known as an intelligent parking assistant. The architecture does not provide the prediction of the availability of free parking space. This architecture allows the operators to reserve a parking space, to reserve for free space, the user needs to register with intelligent parking space. This architecture is used only by authorized users. Vlahogianni et al.[8] proposed a neural network-based model that will predict the occupancy rate of the parking spot. Y. Zheng et al.[9] accomplished a comparative analysis of different data mining techniques such as support vector regression, neural network, and regression tree that will predict the occupancy rate of the parking space. Y. Zheng et al. conclude that the regression tree method is best among the other two algorithms. A comparative analysis is also performed by C. Badii et al.[10] that uses different techniques for analysis, these techniques are Support vector regression, recurrent neural network, Bayesian Regularized Neural Network. It uses Auto-regressive integrated moving average method that will be used for the prediction of parking space accessibility within a particular parking area. There are two different areas of research for the availability of the parking space these are on-street parking area and off-street parking area [10]. Off–street parking approach is limited to inside the garage and On-street parking includes complex features such[11] as weather forecast in their data set. A. Camero et al.[11] proposed a Recurrent Neural Network approach that is based on the prediction of the number of free spaces available in the parking spot. The main aim of the paper is to improve the performance of the Recurrent Neural Network, for this, they introduced a Genetic Algorithm based technique that will find the best configuration for RNN using the Genetic approach.

3. IOT-ENABLED SMART TECHNOLOGIES

IoT was first introduced in 1999 by Kevin Asthon [17]. As this technology is evolving, it promises to connect all the things surrounded by a network and establish communication with less human involvement. Still, the IoT is in the beginning stage, and there is no common design present today. There are no boundaries or guidelines exists to define the definition of IoT. So, depending on this, the application of the IoT has various definitions. Shortly, it is defined as the physical world's things or an environment attached to embedded systems or sensors and connected to the network through wireless or wired networks. These connected devices are called smart objects or devices. IoT deals with linking all the world through the Internet. IoT helps to link trillions of nodes of different objects to the major supermarket web servers and clusters. IoT also helps to incorporate emerging software technology and networking technologies. IoT's main goal is to make the world around us smarter by supplying the data it needs through historical and real-time feeds with the help of data mining algorithms and automatically applying computational knowledge intelligence to make smart decisions. To understand and monitor dynamic environments around us, the data collected from IoT devices will be used to allow higher automation, better decision-making, greater efficiencies, accuracy, and productivity.

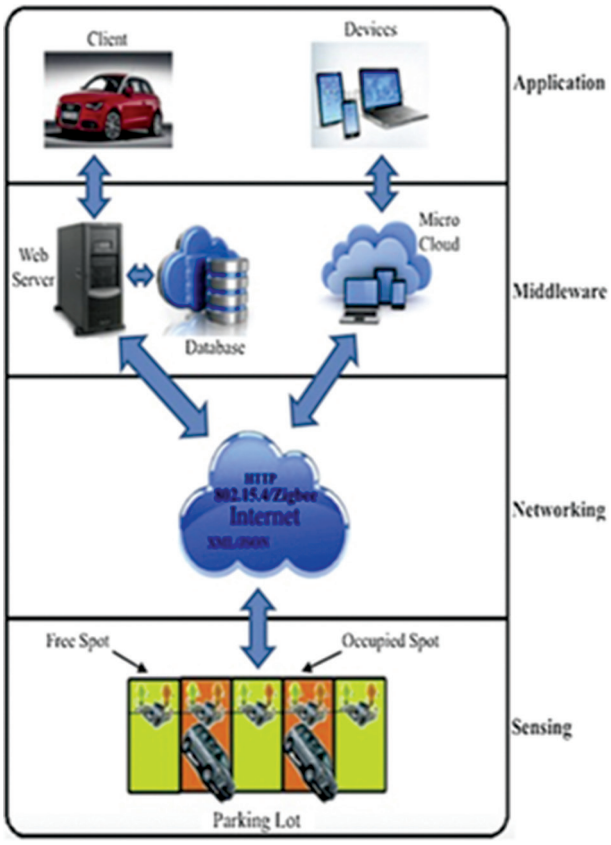

Fig. 1. IoT-Enabled Smart Parking Model

Due to an exponential increase in data volume and sophistication, data mining tasks help us to process such a large volume of data that is the reason we have combined data mining techniques with IoT. As the IoT- enabled system produces a large amount of data in today's time, our main task is to develop an effective model for analyzing, managing, and mining the data. Data mining techniques help us for determining interesting, novel,

and potentially useful patterns from big data sets and applying various techniques to extract hidden information. The IoT enabled smart parking system model is divided into four layers, i.e., application, middleware, networking, and sensing, as shown in Fig. 1[12] . IoT system is classified as the as processing, connectivity, and sensing. The sensing layer involves sensing the speed of cars and humans or any object like accelerometer, temperature sensing, pressure sensing, etc. These can be processed by using various processors such as the hybrid processor, network processor, etc., and these devices connected with the help of technologies like Wi-Fi, GPS, RFID, etc. Processing unit act as an intermediate between the cloud and the sensors. The sensors are connected wirelessly to the processing unit and the processing unit process the data with the help of data mining techniques that will exact the patterns from the large volume of data to predict the location is vacant or not. Using a smart parking model which is based on the sensor and contains a pi-camera to detect the vacant spaces and sends the data to the server, this stored data is accessed by the user [5] .This increases the user's ability to check the status or availability of spaces before setting up their ride. The task here is to optimally use the available resources to reduce the search time and traffic congestion in the region. The application layer serves as an interface to communicate the system with the end-user.

4. DESCRIPTION OF DATA MINING TECHNIQUES

Data mining techniques such as KNN, SVM, and Decision tree, Random Forest, and Ensemble Learning are evaluated and analyze a data set to predict the availability of the parking space is compared here.

4.1. K- NEAREST NEIGHBORS (KNN)

One of the simplest data mining techniques is KNN that is based on the supervised learning technique. It works on the principle of similarity between the new data and the existing data. KNN puts the new data into the category that is most similar to the existing categories. It is a non-parametric algorithm. Samples are classified based on the distance between them. Observations are classified based on the form such as X and Y in the training data set. Here Xi is a vector that will contain the feature values, and Yi is the class label against Xi. Let's take an observation of Xj and we want to predict its class label that is Yj using KNN. The equation used for this observation is given in equation (1), KNN finds J number of observations in X that is similar to the observation Xj:

$$DIS\ Xj,Xi = D(Xj, Xi)1\_i\_n. \quad (1)$$

By using equation (1), the distance between observation Xj and all other observations in X can be calculated using the above formula. When we perform the training on the dataset using the KNN algorithm, then it just stores the new data and at the time of classification, it performs an action on that data and that is the reason it is also known as lazy learner algorithm [20]. Steps used for KNN are as follow:

- Select the n number of neighbors.
- Calculate the Euclidean Distance for the selected number of neighbors.
- Now take n nearest neighbors that are calculated using the Distance formula.
- Among these n neighbors, count the number of data points in each category.
- Assign the new value of the category for which the number of neighbors is maximum.

Let's understand based on an example. Suppose there are two categories, i.e., Category A and Category B, and we have a new data point x1, so this data point will lie in which of these categories. By using K-NN, we can easily identify the category of a particular dataset.

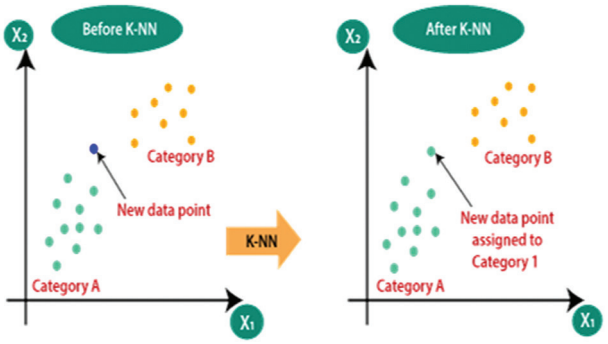

Fig. 2. Example of KNN for assigning the new value to the category [20]

4.2. DECISION TREE

It is a non-parametric supervised learning method that is used for classification and regression. In a decision tree algorithm a tree is constructed by setting different conditions on different branches. Workflow of the decision tree is shown in fig. 3. A decision tree consists of different nodes that are the root node (starting point of the tree), internal nodes (where nodes are divided into different branches), and the external nodes (these are the terminal nodes that will contain homogenous class)[13] .

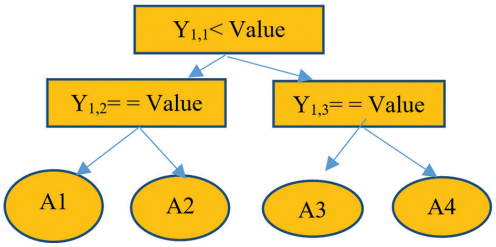

Fig. 3. Decision tree for checking the condition of value

The main aim of using this technique is to create a model that predicts the value of the target variable by learning simple decision rules that are inferred from the data features [20].

4.3 SUPPORT VECTOR MACHINE (SVM)

It is a supervised learning technique that is associated with the learning algorithms that will analyze the data for classification and regression analysis. It is one of the predictive models that is based on statistical learning. It can take two groups of data that is training data and testing data. The SVM learning algorithm maps the training data sets samples to the points in the space to maximize the width of a gap between these two groups. Now the new variables are mapped into the same space and they are predicted that they belong to the group based on which side of the gaps they fall. The goal of the SVM algorithm is to create the best line or decision boundary that can segregate n-dimensional space into classes so that we can easily put the new data point in the correct category in the future. This best decision boundary is called a hyper plane [20]. Pictorial representation of workflow of SVM is shown in fig. 4. In the figure the SVM takes the data from the database that will contain heterogeneous data, it maps the training data into different groups according to their category.

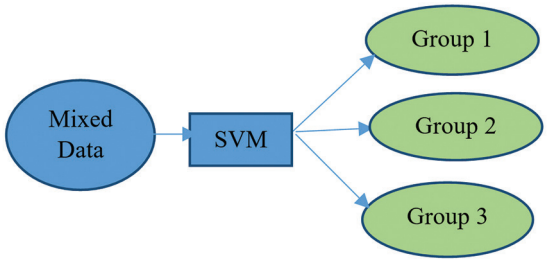

Fig. 4. Block Diagram of SVM

4.4 RANDOM FOREST

Random Forest is a classifier that contains several decision trees on various subsets of the given dataset and takes the average to improve the predictive accuracy of that dataset [20].Random forest is similar to the decision tree algorithm. Multiple independent decision trees are the subparts of the random forest. Each tree in the random forest divide out the class prediction and the class with the most vote become the subtree. Each tree sets a conditional feature differently. Whenever a sample arrives at a root node, then it can be forwarded to all among the subtree. Class label is predicted by each subtree for that specific tester. At the ending stage, the class in the majority is assigned to that specific tester. The working of the random forest algorithm is represented in figure 5.

4.5 ENSEMBLE LEARNING APPROACH

This approach combines multiple data mining techniques. In this paper, we have combined SVM, KNN, Random forest, and Decision tree that will solve the predictability problem of available parking space. In the ensemble learning approach the training data properly trains each model. When the training process is performed the ensemble learning approach feeds the testing data to different models and then each model predicts a class label for each sample in the testing data available in the training set. In the next step, the voting process is performed for the prediction of each sample. Normally two types of voting are available hard and soft voting. Hard voting assigns a class label that is voted by the majority to the sample. In soft voting, average the probability of all the expected outputs. Block diagram of the ensemble learning approach is shown in the given fig. 6.

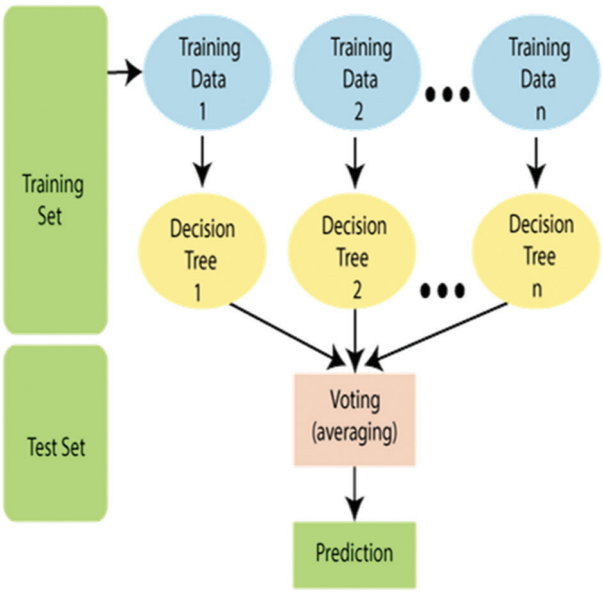

Fig. 5. Working of Random Forest algorithm [20]

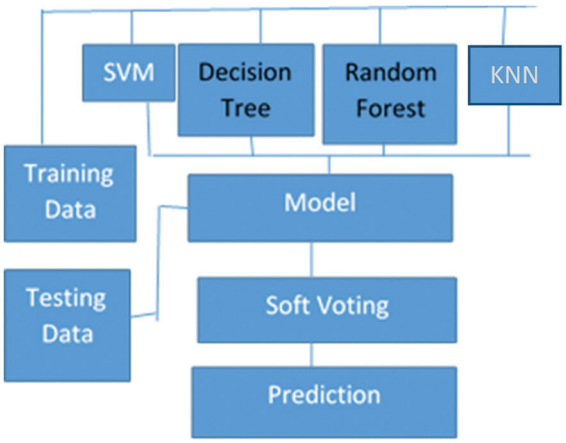

Fig. 6. Block Diagram of Ensemble Learning

5. EVALUATION AND RESULTS

In this paper, five data mining techniques are used that are described in the previous section. These techniques analyze the free parking space and help the drivers to get the most relevant information about the nearest parking space. Sensors are used for the collection of the data that are deployed in a real-time environment i.e. smart city Santander (a city in Spain). In the section below, we are analyzing the performance of five data mining techniques that can be used for the

prediction of the free parking space and also provide a relative analysis of the initial results.

5.1. IOT-ENABLED PARKING DATA SET

The data set used for prediction is PK lot data that contains IoT data which collects the data from the sensors that are deployed in different locations of the smart cities. Parking sensors [16] collect over 3-month of data, this data set was constructed as a part of the Pk lot data. The objective is to predict the available parking space within a time interval of 15 to 25 minutes and also analyze the accuracy of the prediction. The organization of the collected data set is as follow:

1. Parking Identity: A unique identity connected with each parking area.
2. Timestamp: It is a parking space data collection.
3. Period: It refers to the total period for which specific parking space is available or engaged.
4. Start and Finish Time: It refers to the interval of the time during which a parking space status continued to be the same i.e. accessible or engaged.
5. Status: It represents the status of the parking space i.e. accessible or engaged.

The above features are organized in the form of the table 1 given below.

Table 1. Mined Geographies

Key Features	Range
Parking Space Identity	Unique identity of a sensor
Day	7 days of a weak
Starting Hour	0-23 hours of the day
Starting Minute	0-59 minutes of the hour
Ending Hour	0-23 hours of the day
Ending Minute	0-59 Minutes of the hour
Status	0-1(Accessible or Engaged)

Starting an hour and ending hour in Table 1 represent 15 or 25 minutes interval status for any specific space. Data set is collected every minute to provide the exact status of the parking space.

5. 2. SOFTWARE TOOL

Spyder is used for implementation. It is an open- source cross-platform integrated development environment for scientific programming in the python language.

5.3. HYPER-SPECIFICATIONS OF THE DATA MINING TECHNIQUES

In Table 2 we will represent the five specifications for the data mining model that will be used for the analysis of different data mining techniques. Grid search [17] is used to the get best result using the specification for each data mining model.The parameter that is tuned for SVM is "C" and it is the regularization parameter. The strength of this parameter is inversely proportional to C which must be strictly positive. Kernel specifies the type of algorithm to be used and we are using a widely used algorithm that is "rbf".The degree of the kernel is 3 by default. And coefficient used for gamma is "scale "and scale uses 1 / (n_features * X.var()) as value of gamma. Here tolerance is used for stopping the criterion and the size of the cache is 200 by default. Parameters that are tuned for KNN are n_neighbors, distance metric that is Euclidean is used in our case, and n_jobs parallel jobs are used for searching the nearest neighbor in our case. "n_Neighbor" experimented with different numbers of neighbors (2, 6, 8,10,24,49 and 99). "n_neighbors=10" provide the best result. Weights are set as a uniform for all the neighbors' points that are weighted equally. For Decision tree 3 parameters are tuned. Here max depth defines the maximum depth of the tree, over fitting problem occurs if the depth of the decision tree is increased. In our case, max depth is set to 100. Min sample_ leaf defines the number a leaf node can contain, in our case, we set this value equal to 5. For random forest, we tuned 4 parameters that are max depth that is similar to the decision tree parameter. The value of both the parameters are the same in our case. "n_estimator" is used to define the number of trees in the forest and in our case we set this value equal to 100. "Criterion=entropy" is works on information gain. Here information gain is related to the decrease in entropy after every split. For ensemble learning 3 parameters are tuned "estimator" defines the techniques used by ensemble learning, in our case we use SVM, KNN, Random forest, Decision tree. Another parameter used for ensemble learning is the weight that is used for defining the priority of each estimator used. The voting classifier is used for assigning the weights to the estimators and we have assigned equal weights to all the classifiers except the decision tree. High priority is assigned to the decision tree because the performance of the decision tree is better among all data mining techniques when it is used to predict the available parking space. These hyper-specifications are shown in the tabular form in table 2.

5.4. EVALUATION PARAMETERS

The parameters that are used for the valuation and comparing data mining techniques are given below.

1. **Precision:** It can be defined as the division of all the samples that are labeled as positive samples and that samples are positives[14]. The mathematical formula is given below.

$$\textbf{Precision} = \frac{\textbf{True Positive}}{\textbf{True Positive+False Positive}}$$

2. **Recall:** It is defined as a fraction of all the positive samples; all the samples are labeled as positive [16].The equation of recall is given below.

$$\textbf{Recall} = \frac{\textbf{True Positive}}{\textbf{True Positive+False Positive}}$$

3. **Accuracy:** It is the ratio of the appropriately forecasted values in the total number of the available samples that is communicated in the following equation.

$$\textbf{Accuracy}=\frac{\#Accurate\ Predictions}{\#Total\ Samples}$$

4. **F1-Score:** The harmonic mean of recall and precision is defined as F1 score [14], the mathematical definition is given below.

$$\textbf{F1-Score}=\frac{2*(Recall*Precision)}{Recall+Precision}$$

Table 2. Hyper-Specification of Data Mining Techniques Used for Analysis

SVM		KNN		Decision Tree		Random Forest		Ensemble Learning	
Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
Kernal	rbf	n-neighbors	10	Max-depth	90	Max_depth	90	estimator	SVM, Decision Tree, KNN, Random Forest,
Degree	3	metric	euclidean	criterion	entropy	criterion	entropy	voting	soft
Gamma	Scale	n-jobs	nill	Min_sample	6	Min_samples	1	weights	1,2,1,1
CoefO	0.0	weights	uniform			N_estimators	100		

K-Fold Cross Validation: This method is used for testing the over fitting and to evaluate the consistency of the specific data model. In the k-fold authentication method, a dataset is divided into k equal sets in our case the value of k is 5. In the given k set one data set is used as a testing data set and all the remaining data sets are used as training data sets. In our case, we will configure it to generate 1000 samples each with 20 input features, 15 of which contribute to the target variable.

5.5. PERFORMANCE EVALUATION

In this section, we will provide the evaluation performance of KNN, decision tree, random forest, SVM, and Ensemble learning algorithms. A comparative analysis of 15-minute and the 25-minute predictions was done after considering 50% and 70% thresholds for both predictions. "Data mining algorithm has a capability of predicting a probability of class membership and this must be interpreted before it can be mapped to a crisp class label. The threshold is used to achieve the goal where all the values equal or greater than the threshold are mapped to one class and all other values are mapped to another class". To improve the performance of the results we have considered 50% and 70% threshold values. Why we need to set threshold values because when we are working with real-time data then we have received a variety of data values and if we compare all the values on a single threshold then results never be that much impressive. We have chosen the 50% and 70% threshold because we want results to be more reliable. When we work on real-time data the values are not of the same nature it may vary and depending on different values we are showing the result using different thresholds.

5.5.1. 15-Minute Prediction Rationality (50% Threshold)

Table 3 given below represents the cross-validation score of SVM, KNN, Decision tree, random forest, and Ensemble learning technique that uses 15-min prediction with 50% threshold. During computation, it is shown that SVM has the lowest performance with an average of 64.64% precision, 51.08% recall, 71.72% accuracy, and 56.57% F1-score. One of the simplest data mining models is KNN that is outperformed with SVM and the results are 72.03% precision, 66.35% recall, 77.72% accuracy, and 69.13% F1-Score. The performance of the random forest is even better and the results are 85.91% precision, 79.12%recall, 85.49%accuracy, and 82.36%F1-Score. As shown in the table that the performance of the decision tree and the ensemble technique both techniques are quite close to each other. The average precision of decision tree is 92.13% while an average precision value of the ensemble learning is 93.71%.The average recall score of the decision tree is 90.39% and the average recall score of the ensemble learning is 89.23%. The average accuracy of the decision trees 93.16% while the average accuracy of ensemble learning is 93.23% an improvement of only 0.07%. The average F1-Score of the decision tree is 91.70%, while ensemble learning shows 91.99%. Results are shown in the form of a graph in figure 7.

Table 3. Average cross Validation of each Data Mining technique (15-minute prediction validity with 50% threshold)

Metrics	SVM	KNN	DT	RF	EL
Precision	64.64	72.03	92.13	85.91	93.71
Recall	51.08	66.35	90.39	79.12	89.23
Accuracy	71.72	77.72	93.16	85.49	93.23
F1-Score	56.57	69.13	91.70	82.36	91.99

"SVM= Support Vector Machine, KNN=K-Nearest Neighbors, DT= Decision Tree, RF= Random Forest, EL= Ensemble Learning"

5.5.2. 15-Minute Prediction Rationality (70% Threshold)

Table 4 given below represents the cross-validation score of KNN, Decision tree, random forest, SVM, and Ensemble learning techniques that use 15-min prediction with a 70% threshold. After considering the 50% threshold it is clear that the performance of the SVM

is worst among all the given data mining techniques. SVM shows 72.24% accuracy with 62.91% average precision, 50.54% average recall, and 56.12% average F1-Score. The KNN shows 78.28% accuracy, 72.20% precision, 66.24% recall, and 69.10% average F1-score. The Random forest average accuracy was 85.60%, while its average precision was 86.02%, its average recall value was 79.80%, and F1-Score was 82.27%. From the given table 4 it is clear that the performance of the decision tree and the ensemble learning techniques shows the quite same performance both at the top end. The average accuracy value for decision tree and ensemble learning is 93.40% and 93.30% respectively, precision value is 92.12% and 94.14% respectively, average recall is 90.31% and 88.25% respectively, and F1-Score is 91.70% and 91.51% respectively. Results are shown in the form of a graph in figure 8.

Table 4. Average cross Validation of each Data Mining technique (15-minute prediction validity with 70% threshold)

Metrics	SVM	KNN	DT	RF	EL
Precision	62.91	72.20	92.12	86.02	94.14
Recall	50.54	66.24	90.31	79.80	88.25
Accuracy	72.24	78.28	93.40	85.60	93.30
F1-Score	56.12	69.10	91.70	82.27	91.51

"SVM= Support Vector Machine, KNN= K-Nearest Neighbours, DT= Decision Tree, RF= Random Forest, EL= Ensemble Learning"

5.5.3. 25- Minute Prediction Rationality (50% Threshold)

In the given section, we will represent the comparative analysis using 25-minute prediction validity with a 50% threshold. Table 5 represents the average cross-validation score for each data mining technique. The SVM shows the lowest score among the given techniques. The average precision value of the SVM is 64.90 % and the average recall value is 51.28%. F1-score depends on the precision and the average recall value, SVM remains low at 56.67% and the average accuracy value of the SVM is 71.93%. Now consider the average value of KNN as we compare the performance of KNN is better than SVM. The performance of KNN is 73.16% average precision value, 67.77% is average recall, 78.72% is average accuracy, and average F1- Score is 70.36%. If we compare the performance of the Random forest with these two techniques then the result is much better than these first two, with 81.43% precision, 72.77% average recall, 81.48% average accuracy, and an F1-Score is 76.86%. And if we take Decision tree and ensemble learning they are following the same trend. The performance of these two techniques is similar to the previous one. The average accuracy of the decision tree and the ensemble learning is 86.65% and 87.72% respectively, the average precision value is 84.63% and 87.64% respectively, and the average recall is 83.36% and 82.55% respectively, and F1-score is 84.01.and 85.02 respectively. Results are shown in the form of a graph in figure 9.

Table 5. Average cross Validation of each Data Mining technique (25-minute prediction validity with 50% threshold)

Metrics	SVM	KNN	DT	RF	EL
Precision	64.90	73.16	84.63	81.43	87.64
Recall	51.28	67.77	83.36	72.77	82.55
Accuracy	71.93	78.72	86.65	81.48	87.72
F1-Score	56.67	70.36	84.01	76.86	85.02

"SVM= Support Vector Machine, KNN= K-Nearest Neighbors, DT= Decision Tree, RF= Random Forest, EL= Ensemble Learning"

5.5.4. 25-Minute Prediction Rationality (70% Threshold)

In this, we will represent the performance result of all the data mining techniques with 25-min rationality with 70% threshold value. From the given table it is clear that the threshold value did not affect the standing of the data mining techniques for the configuration. The performance of the decision tree and the ensemble learning is always remains in the top two among all the techniques in terms of all the evaluation of the metrics. Decision tree shows 84.41% precision 83.12% recall, 86.81% accuracy and 83.76% F1-Score. The performance of the ensemble learning is 88.03% precision, 81.51% recall, 87.71% accuracy, and 84.63% F1-score. The next best technique is the Random forest technique with an average precision value is 81.85%, the average recall is 72.57%, the average accuracy is 82.16%, and F1-Score is 76.94%. If we compare the performance of the KNN and SVM then the KNN outperformed SVM with 74.35% precision, 67.35% recall, 79.37% accuracy, and 70.23% F1-score. The performance of the SVM is as follows. The average precision value is 64.34%, the average recall is 50.84%, the average accuracy is 73.08% and F1-Score is 56.79%. Results are shown in the form of a graph in figure 10. Table 6 represents the cross-validation of each technique using the 70% threshold.

Table 6. Average cross Validation of each Data Mining technique (25-minute prediction validity with 70% threshold)

Metrics	SVM	KNN	DT	RF	EL
Precision	64.34	74.35	84.41	81.85	88.03
Recall	50.84	67.35	83.12	72.57	81.51
Accuracy	73.08	79.37	86.81	82.16	87.71
F1-Score	56.79	70.23	83.76	76.94	84.63

"SVM= Support Vector Machine, KNN= K-Nearest Neighbours, DT= Decision Tree, RF= Random Forest, EL= Ensemble Learning"

For a better understanding of the tables, results are shown in the form of figures. In figures 7-10, comparative analysis results of five data mining techniques that are fused with IoT datasets are shown. Comparative analysis is performed using well-known techniques that are SVM, KNN, Decision tree, Random Forest, and

Ensemble Learning. For evaluation of the results, we used 4 parameters that are precision, recall, accuracy, and F1-Score. The K-fold method is used to evaluate the consistency of the specific data model. In the k-fold authentication method, a dataset is divided into 5 equal sets. In the given k set one data set is used as a testing data set and all the remaining data sets are used as training data sets. In our case, we will configure it to generate 1000 samples each with 20 input features, 15 of which contribute to the target variable. An experiment is conducted using 50% and 70%threshold using 15-minute and 25-minute predictive rationality. Using a 50% threshold, accuracy is around 93% and the threshold is increased to 70% then accuracy is around 82%. After analyzing all the results of the data mining techniques it is clear from evaluation parameters that the performance of the decision tree and the ensemble learning is better among all other data mining techniques. And if we compare the performance of the decision tree and ensemble learning technique then the decision tree outperformed the ensemble technique. So we can say that the optimized technique among all the techniques is the decision tree.

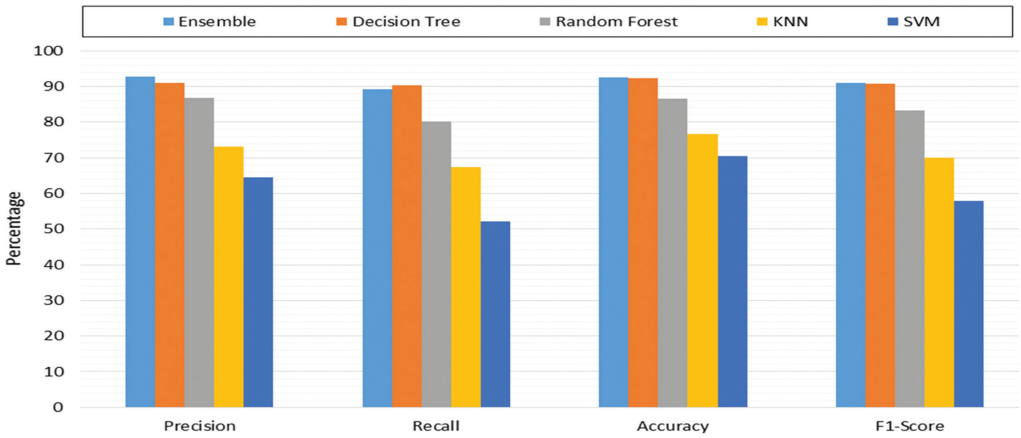

Fig. 7. Comparative analysis using different Data Mining Techniques where predictive rationality=15 minute, threshold=50%

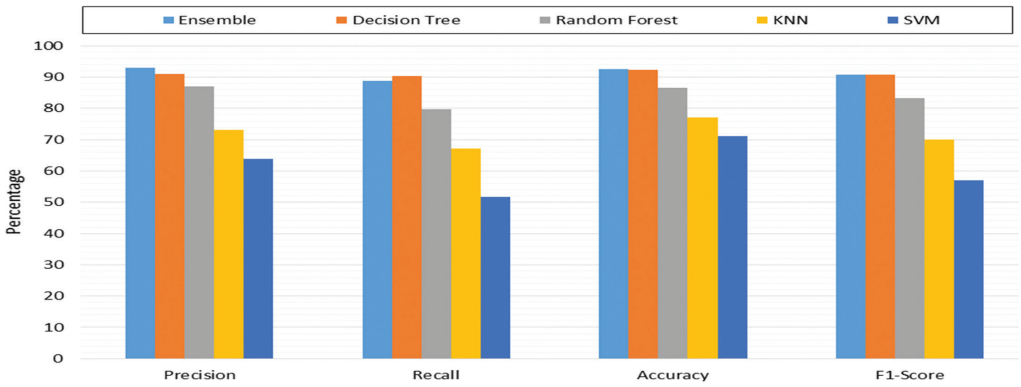

Fig. 8. Comparative analysis using different Data Mining Techniques where predictive rationality=15 minute, threshold=70%

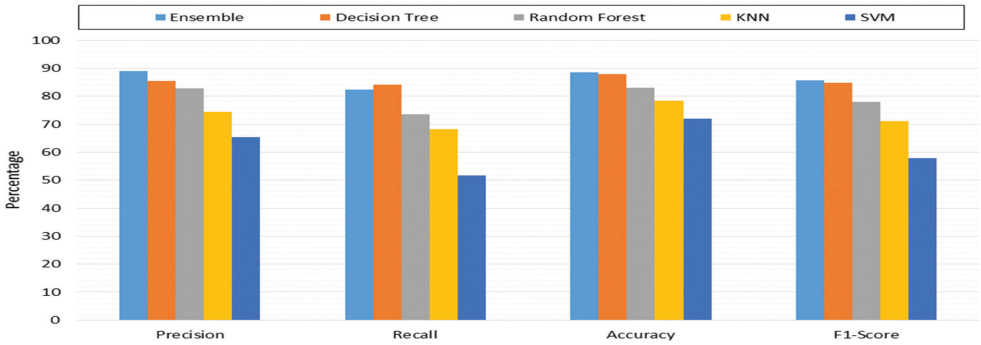

Fig. 9. Comparative analysis using different Data Mining Techniques where predictive rationality=25 minute, threshold=50%

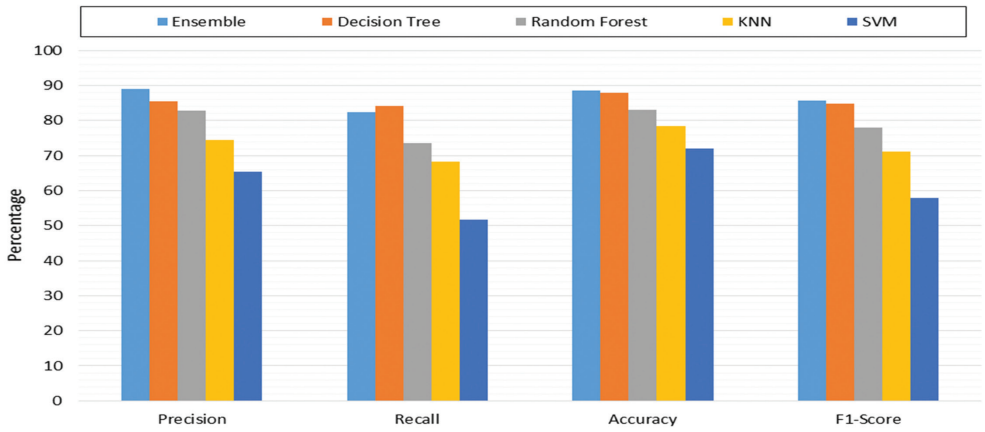

Fig. 10. Comparative analysis using different Data Mining Techniques where predictive rationality=25 min, threshold=70%

6. CONCLUSION

In this paper, we have fused two technologies that are IoT and data mining techniques to predict free parking space. IoT devices generates a large volume of raw data that cannot be recognized for meaningful knowledge unless the data are processed. For that reason, we chose the data mining techniques that will be preprocessed such a large volume of historical data to model the behavior so that it will help to predict the availability of the free parking space. We have analyzed well-known data mining techniques and the originality of the paper is the comparative analysis of the techniques using PK lot data that will imitate the actual environment. The main aim of this paper is to find the optimized data mining technique that will help us to predict the free parking space availability in the parking lot. We performed comparative analysis using well-known 5 data mining techniques: Support Vector Machine (SVM), K-Nearest Neighbor, Decision tree, Random Forest, and Ensemble Learning. The K-fold cross-validation method is used for numerical calculation of the results. For evaluation metrics, we have used precision, recall, accuracy, and F1-Score. An experiment is conducted using 50% and 70%threshold using 15-minute and 25-minute predictive rationality. One of the main aims of the paper is to find the technique that will give better results for predictive analysis. Among all the techniques one of the simple techniques is the KNN mining technique. Based on the result, we can conclude that the decision tree is an optimized solution for the prediction of the availability of the parking space. Ensemble learning is the next closest technique to get better results. So we can say that the optimized technique among all the techniques is the decision tree.

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Fuzzy and Position Particle Swarm Optimized Routing in VANET

Original Scientific Paper

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Abstract *– In Intelligent Transport Systems, traffic management and providing stable routing paths between vehicles using vehicular ad hoc networks (VANET's) is critical. Lots of research and several routing techniques providing a long path lifetime have been presented to resolve this issue. However, the routing algorithms suffer excessive overhead or collisions when solving complex optimization problems. In order to improve the routing efficiency and performance in the existing schemes, a Position Particle Swarm Optimization based on Fuzzy Logic (PPSO-FL) method is presented for VANET that provides a high-quality path for communication between nodes. The PPSO-FL has two main steps. The first step is selecting candidate nodes through collectively coordinated metrics using the fuzzy logic technique, improving packet delivery fraction, and minimizing end-to-end delay. The second step is the construction of an optimized routing model. The optimized routing model establishes an optimal route through the candidate nodes using position-based particle swarm optimization. The proposed work is simulated using an NS2 simulator. Simulation results demonstrate that the method outperforms the standard routing algorithms in packet delivery fraction, end-to-end delay and execution time for routing in VANET scenarios.*

Keywords*: VANET, Position Particle Swarm Optimization, Fuzzy Logic, coordinated metrics, candidate nodes*

1. INTRODUCTION

VANETs have recently attracted attention for their ability to enable inter-vehicle communications. As a result, efficient routing is one of the methods for improving vehicular traffic safety. Ad hoc On-demand Distance Vector adaptation in the Virtual Node layer (VNA-ODV) [1] improves packet delivery fraction and latency. However, with so many messages to send, so much overhead, and so many collisions, the network lifetime was reduced. [4] proposes FB QoS-Vanet, a QoS-based routing protocol that accommodates applications with QoS requirements. Long Lifetime Anypath (LLA) [16] was created to address connection link stability, ensuring stable communication pathways to reduce overhead and extend the network's life. Clustering and cluster-based routing techniques were described in [2] to obtain a higher delivery ratio and much lower overhead for delay-tolerant networks. In [7], a novel polynomial-time sequential topology inference algorithm was designed to reduce probing overhead and handle node dynamics.

According to recent experiments, multi-path fading and co-channel interference influence packet delivery in wireless mesh networks. [9] proposed a Cross-Layer Channel Adaptive Routing protocol to improve channel and transmission rate. Aside from significant routes, path maintenance and latency were also considered, which identified and corrected the point of failure before performing recovery action. However, increased scalability posed severe threats to energy consump-

tion. To address energy consumption issues, [21] designed an energy-aware clustering algorithm that addressed energy consumption and improved network lifetime. The method described in [15] is applicable in dynamic network conditions and compatible with both vehicle-to-infrastructure and vehicle-to-vehicle communication modes. The authors of [3] designed a bi-objective optimization formulation to analyze link-stability to ensure energy-aware routing in distributed wireless networks. [5] developed a stochastic model with a density-dependent velocity profile for optimizing both transport and communication networks. [14] proposed interference-aware routing based on passive measurements to improve routing efficiency. In [10], the authors investigated some traditional features of the particle swarm in search of properties.

We propose Position Particle Swarm Optimization with Fuzzy Logic for vehicular ad hoc networks with correlated metrics, the cores of a Collective Coordinated Fuzzy Logic algorithm and a Position-based Particle Swarm Optimization algorithm in this paper. The Collective Coordinated Fuzzy Logic algorithm selects candidate nodes by considering correlated metrics, bandwidth, node energy, and mobility to improve packet delivery fraction in VANET. A position-based particle swarm optimization algorithm is proposed to reduce the execution time during routing, which improves the efficiency of routing in VANET by eliminating the inertial weight and control coefficients in PSO. As a result, it can enhance VANET routing efficiency and extend network lifetime.

The remainder of the paper is structured as follows: section 2 reviews some related works on routing algorithms. section 3 suggests using fuzzy logic to optimize position particle swarms, and section 4 contains a detailed description of the simulation results as well as discussions. Finally, section 5 brings the work to a close.

2. RELATED WORKS

The works of literature related to link correlation and data acquisition concerning routing are described in this section. A novel link correlation aware opportunistic routing scheme was designed in [18] by applying link correlation metrics. In [13], a framework for secure and data acquisition methods was presented using advanced encryption standard. Another acknowledgement-based broadcast protocol was investigated in [17] using connected dominating sets to provide higher reliability and message delivery.

Recently, VANETs have emerged as one of the most demanding research areas, ensuring safety in Intelligent Transport system networks. In [8], a Trajectory-based Statistical Forwarding scheme was presented in the road network that ensured data forwarding and reduced the packet delivery delay fraction through an optimal rendezvous point. However, with the increasing number of vehicles, the routing overhead also increased. To reduce the routing overhead, In [22], a neighbour coverage-based probabilistic rebroadcast protocol was designed aiming at reducing the number of retransmissions. In [6], a machine learning-based adaptive routing protocol was developed based on reinforcement learning for underwater sensor networks.

Geographic routing is attractive since the routing state needed for greedy forwarding at each node is highly based on the network size. In [11], a geographic routing protocol for d-dimensional spaces was investigated to reduce the node churn rate. In [20], opportunistic routing was considered to estimate the traffic flow density based on the road traffic flow and geographic topology. Robust routing and scheduling mechanisms designed in [19] in dynamic conditions aim to improve routing efficiency. Another method to address reliable packet delivery using beacon distance vector-based global routing and distance vector-based local routing was designed in [12] to achieve scalability and efficiency in a wide range of scenarios.

3. POSITION PARTICLE SWARM OPTIMIZATION WITH FUZZY LOGIC(PPSO-FL)

The proposed PPSO-FL focuses on enhancing the routing operations in VANETs, with the amalgamation of collectively coordinated metrics and position-based particle swarm optimization. In this section, a routing operation is described by starting with a network model, followed by Fuzzy Logic-based Candidate node Selection, and finally, ends with an optimal route through Position-based Particle Swarm Optimization.

3.1. NETWORK MODEL

Let us consider a unidirectional network of length 'l'. For vehicles' $V= v_1, v_2,...,v_n$' on the network, there occurs 'D' discrete speed levels with speed 'v_i' seen by the observer as 'λ_i'. Therefore, the overall vehicle arrival rate is expressed as given below:

$$\mathrm{VAR} = \sum_{i=1}^{n} \lambda_i \quad (1)$$

With the above vehicle arrival rate 'VAR', the probability of occurrence of speed 'v_i' is expressed as given below:

$$Prob_i = \frac{\lambda_i}{VAR} \quad (2)$$

Let us now model a network topology in the form of a graph' $G=(V,E)$'. Here, vehicles (referred to as nodes) represent vertices set '$V=\{v_i\}$' and links to the set of time-dependent edges '$E=\{e_{ij}\}$' with every node having the same transmission radius 'R'. An edge 'e_{ij}' is said to exist if the distance '$Dist_{ij}$' between two nodes'v_i' and 'v_j' is less than or equal to 'R' and is expressed as given below:

$$E = \{e_{ij} | v_i, v_j \in V, Dist_{ij} \leq R\} \quad (3)$$

The problem lies in designing an optimized routing method elaborated in the forthcoming subsections with the above network model.

3.2. FUZZY BASED CANDIDATE SELECTION

The PPSO-FL uses collectively coordinated metrics, including bandwidth, node energy, and mobility of the node, to identify the feasible links between the nodes using the candidates. The efficient nodes from the set of nodes in VANET are selected as candidates. This selection is made based on the improved bandwidth 'BE' rate, possessing high energy '$E(T)$' and low mobility 'DR_{ij}' pattern using a fuzzy logic model. Fig. 1 shows a simple fuzzy logic model for candidate node selection.

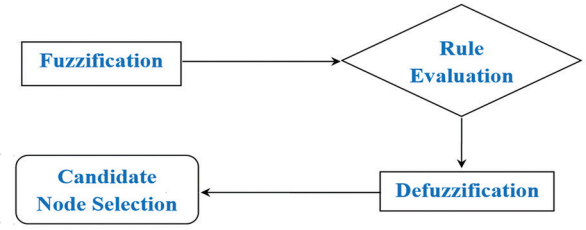

Fig. 1 Candidate node selection using the fuzzy logic

Once the network is deployed with the nodes, each node broadcasts a '$HELLO$' packet to its neighbour nodes. The broadcasted packet includes the source node identifier 'v_i', Destination node 'v_n' and the collective coordinated metrics bandwidth '$v(B)$', node energy '$v(E)$' and mobility of the node '$v(M)$' respectively, as shown in Fig. 2.

v_i	$v(B)$	$v(E)$	$v(M)$	v_n

Fig. 2 Format of hello message

The candidate nodes are ascertained with the aid of the fuzzy logic model. Fig. 3 shows the process of Fuzzy Logic-based Candidate node Selection.

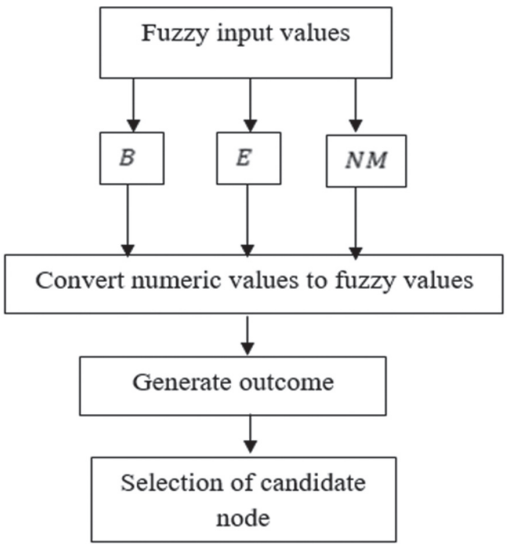

Fig. 3 Process of Fuzzy Logic-based Candidate node Selection.

As shown in Fig. 3, metrics bandwidth '$v(B)$', node energy '$v(E)$', and mobility of the node '$v(M)$' are given as the input to the fuzzy model. Whenever a source node in the network needs to transfer message packets to the destination node, the PPSO-FL evaluates the local bandwidth 'B' based on the transmission range of neighbours '$R(v_j)$'. Thus, the node monitors the transmission channel, measures the bandwidth estimation, and is expressed below:

$$BE = TCC * \frac{T_{idle}}{T_{tot}} \tag{4}$$

From (4), the bandwidth 'BE' is measured based on the product of transmission channel capacity 'TCC' and the ratio of the idle time 'T_{idle}' to the overall time 'T_{tot}'. Once the bandwidth is estimated, the node energy is evaluated. Let us consider a node with initial energy as 'E_i', then, the energy consumed over a period of time 'T' is expressed as given below:

$$E(T) = DP_t + DP_r \tag{5}$$

From (5), the energy consumed '$E(T)$' is the summation of the number of data packets transmitted, 'DP_t' and received 'DP_r' over some time 'T'. Finally, the node mobility of 'v_i' concerning node 'v_j' is evaluated based on the distance rate 'DR_{ij}' and is expressed as given below:

$$DR_{ij} = \frac{\sqrt{(v_i - v_b)^2 + (v_b - v_j)^2}}{R} \tag{6}$$

Where '(v_i - v_b)' and '(v_b - v_j)' are the Cartesian products of nodes 'v_i' and 'v_j' respectively with 'R' corresponding to the transmission range. The fuzzification converts the numeric values to fuzzy values from the above-evaluated bandwidth rate (6), energy, and node mobility. Followed by this, the membership functions are evaluated as expressed below:

$$MF(Fuzzy_i) \rightarrow MAX(BE), MAX\left(E(T)\right), MIN\left(DR_{ij}\right) \tag{7}$$

With the membership function measured using (7), the rule evaluation with higher bandwidth, node possessing high energy and low mobility is expressed below:

$$f(outcome) = \begin{cases} low, bandwidth\ is\ high, energy\ is\ high \\ \quad and\ node\ mobility\ is\ low \\ high, bandwidth\ is\ low, energy\ is\ low \\ \quad and\ node\ mobility\ is\ high \end{cases}$$

The interpretation of the above rule is that higher bandwidth, energy, and low node mobility are a desirable selection which yields a high collective coordinated outcome. Finally, the PPSO-FL produces a numeric result based on the output membership function called defuzzification and is expressed below:

$$D = \frac{Fuzzy_i * MF(Fuzzy_i)}{MF(Fuzzy_i)} \tag{8}$$

From (8), a node with the maximum collective coordinated outcome is selected as the candidate node. Fig. 4 shows the Collective Coordinated Fuzzy Logic algorithm.

Input: Nodes' $V = v_1, v_2, \ldots, v_n$', Node Mobility' M', Bandwidth' B', Energy' E', Candidate Node '$CN = cn_1, cn_2, \ldots, cn_n$'

Output: **Optimal Routing**

1: **Begin**

2: **For each** HELLO message broadcasted by nodes' V' with input values' B', 'E' and 'M' to neighboring nodes

3: Measure Bandwidth Estimation using (4)

4: Measure Energy consumed over a while 'T' using (5)

5: Measure node mobility using (6)

6: Evaluate membership functions using (7)

7: Generate the outcome based on the results of (5), (6), and (7)

8: If bandwidth is high, energy is high, and node mobility is low

9: Then the outcome is low

10: Node is selected as candidate node 'CN'

11: **Else** outcome is high

12: Go to step 2

13: **End if**

14: **End for**

15: **End**

Fig. 4 Collective Coordinated Fuzzy Logic algorithm

As shown in Fig.4, the Collective Coordinated Fuzzy Logic algorithm uses fuzzy logic for the candidate node selection. If the source node needs to send a data packet to the destination node in the network, the PPSO-FL initially calls the fuzzy logic that selects the candidate nodes through which the data packets are sent in VANET. In the PPSO-FL, the candidate nodes are selected using the Collected Coordinated metrics, namely, Bandwidth estimation, Node energy, and node mobility. The nodes with high bandwidth, high energy, and low mobility are selected as the candidate node through which the data packets are sent. As a result, the packet delivery fraction improves and the end-to-end delay for route identification decreases.

3.3. POSITION-BASED PSO

Once the candidate nodes are identified, routing must be performed, which is one of the challenging tasks in VANET. Therefore, it becomes difficult to identify an optimal combination for the quality of service in VANET. By applying Particle Swarm Optimization, optimal routing in VANET is easily measured. However, the control parameters in PSO play a major role with the slight differences in the control parameter that results in different performances. Hence, the PPSO-FL, Position-based PSO is designed to minimize the dependency of the control parameters and therefore improve the efficiency of routing in VANET.

Let us consider the (particles) candidate nodes 'CN' as a set of random solutions through which the source node 'v_i' sends the data packets 'DP_i' and finally reaches the destination node 'v_n'. Each candidate node 'cn_i' is considered to be a potential solution (route) that moves in the search space (i.e. network with transmission range 'R') following the optimal candidate node.

Each candidate is made up of two 'n' dimensional vectors, with 'n' representing the entire network's dimensionality, called the position vector 'p_i' and velocity vector 'v_i' are expressed as given below.

$$pv_i = (pv_{i1}, pv_{i2} \ldots, pv_{in}) \quad (9)$$

$$vv_i = (vv_{i1}, vv_{i2}, \ldots, vv_{in}) \quad (10)$$

Where 'n' corresponds to the candidates in the network.

$$vv_i(T+1) = \omega * vv_i(T) + ac_1 * rn_1 * \left(P_{best} - pv_i(T)\right) + ac_2 * rn_2 * \left(G_{best} - pv_i(T)\right) \quad (11)$$

$$pv_i(T+1) = pv_i(T) + vv_i(T+1) \quad (12)$$

Where 'vvi' and 'pv_i' corresponds to the velocity and position vector for the 'ith' candidate node in the network. In (11), 'P_{best}' corresponds to the previous best candidate node whereas, 'G_best' represents the global best candidate node in the network with 'rn_1' and 'rn_2' corresponding to the random numbers. Inertial weight is denoted as 'ω' whereas, 'ac_1' and 'ac_2' represent the acceleration coefficient values.

$$\lim_{T\to\infty}\left(pv_i(T)\right) = \frac{ac_1 * P_{best} + ac_2 * G_{best}}{ac_1 + ac_2} \quad (13)$$

Where the position of 'P_{best}' and 'G_{best}' is expressed in (13). Based on the convergence characteristic of PSO, the PPSO-FL uses Position-based PSO (PPSO), each particle (i.e. candidate nodes) only has a position vector and eliminates the velocity vector. Therefore, PPSO in the PPSO-FL eliminates the parameters, 'ω, ac_1 and ac_2', minimizing the execution time for routing. The updated positional value based on the PPSO-FL using PPSO is expressed as given below.

$$pv_i(T) = M * \left(\frac{G_{best} + P_{best}}{2}, |G_{best}, P_{best}|\right) \quad (14)$$

$$pv_i(T) = M * \left(\mu(G_{best}, P_{best}), \sigma(G_{best}, P_{best})\right) \quad (15)$$

Where 'M (*)' corresponds to the updated positional value based on the average '$(G_{best}+P_{best})/2$' and standard deviation '$|G_{best}, P_{best}|$' respectively. Let us consider a source node 'S', candidate nodes 'v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8, v_9, v_{10}, v_{11}' through which the data packets 'DP_i' has to be sent to the destination node 'D' respectively. Fig. 5 shows the construction of the optimized routing model using PPSO with three possible routes identified.

As shown in Fig. 5, three routes exist between the source node 'S' and destination node 'D'. They are (i) route 1: '$S \rightarrow cn_1 \rightarrow cn_2 \rightarrow cn_8 \rightarrow D$', (ii) route 2: '$S \rightarrow cn_3 \rightarrow cn_5 \rightarrow cn_6 \rightarrow D$' and (iii) route 3: ' $S \rightarrow cn_4 \rightarrow cn_7 \rightarrow cn_9 \rightarrow cn_{10} \rightarrow cn_{11} \rightarrow D$' respectively. By applying the proposed PPSO, the optimal route is '$S \rightarrow cn_3 \rightarrow cn_5 \rightarrow cn_6 \rightarrow D$'.

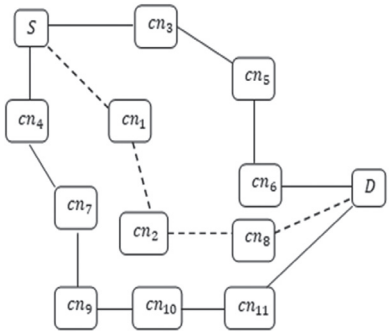

Fig. 5 Construction of optimized routing model

Fig. 6 shows the PPSO algorithm, aiming at improving the identification of optimal routes by the candidate nodes, therefore improving the routing efficiency in VANET.

Input: Source node 'S', Destination node 'D', candidate nodes' $CN = cn_1, cn_2, .., cn_n$', Data Packets' $DP = DP_1, DP_2 \ldots, DP_n$', Global best '$G_{best}$', previous best candidate node 'P_{best}'

Output: Reduced Overhead

1: **Begin**
2: **For** each Source node 'S' with Data packets' DP' to be sent
3: **For** each candidate nodes' CN'
4: **Repeat**
5: Obtain position vector using (9)
6: Obtain velocity vector using (10)
7: Adjust new position vector using (12)
8: Obtain the position of Global best 'G_{best}' and previous best candidate node 'P_{best}' using (13)
9: Measure updated positional value using (15)
10: **Until** (the optimal route is identified)
11: **End for**
12: **End for**
13: **End**

Fig. 6 PPSO Algorithm

In this paper, a position-based particle swarm optimization algorithm by evaluating the candidate nodes is presented. Using the optimal candidate node and randomly adjusting the candidate nodes, the particles' inertia is heterogeneous. The diversity of learning between the particles (i.e. candidate nodes) is increased, and the candidate nodes quickly identify the optimal solution, which in turn paves the way for routing efficiency.

4. SIMULATION AND RESULTS ANALYSIS

An extensive simulation has been performed to investigate the proposed PPSO-FL routing optimization. The results outcomes have been compared against the two existing routing algorithms, namely, Virtual Node Ad hoc On-demand Distance Vector (VNAODV) [1] and Long Lifetime Anypaths (LLA) [16].

4.1. SIMULATION ENVIRONMENT AND PARAMETERS

NS-2.35 network simulator has been used in the simulation of the PPSO-FL method. NS-2 simulator has been used to create mobility log files with the simulation parameters listed in Table 1. Once the network is deployed with maximum traffic flow based on the simulation parameter listed, the simulation has been performed in different VANET scenarios

Table 1 Simulation parameters

Parameter	Value
Node density	10, 20, 30, 40, 50, 60, 70
Simulation area	2000m × 2000m
Vehicle speed	15 m/s
Transmission range	300m
Transmission rate	4Mbps
Data packet size	1000 bytes
Simulation time	1400s
Vehicle speed	1.4 – 16.7 m/s

4.2. PERFORMANCE METRICS

Packet Delivery Fraction (PDF): routing efficiency is defined as the total number of data packets sent into the network for every successfully delivered data packet. In other words, the PDF, a measure for routing efficiency, is the ratio of total data packets received over total data packets sent by the source during the simulation period. PDF characterizes the correctness of the routing optimality.

$$PDF = \left(\frac{DP_r}{DP_s}\right) * 100 \tag{16}$$

Where the 'PDF' is obtained using the data packets received 'DP_r' and sent 'DP_s'.

End-to-end delay: The average end-to-end delay is the average time needed to transfer a data packet from the source vehicle (i.e. node) to the destination vehicle. The lower is the end-to-end delay, the better the application performs.

$$ETED = \frac{Time\ (DP_r) - Time\ (DP_s)}{(DP_r)} \tag{17}$$

Execution time during routing: The execution time for routing is the time taken for obtaining a route path concerning different routes in the network.

$$ET = \sum_{i=1}^{n} R_i * Time\ (R_i) \tag{18}$$

Where the execution time 'ET' is measured using the number of routes'R_i' identified to the time taken for routing '$Time\ (R_i)$'.

4.3. RESULT ANALYSIS

The results in Table 2 show that the proposed PPSO-FL method outperforms the two existing methods VNAODV [1] and LLA [16] in terms of packet delivery fraction. It is noteworthy that the proposed PPSO-FL method considers collectively coordinated metrics concurrently, whereas the existing methods VNAODV and LLA, consider a single objective.

When the data packets are of equal size, the proposed PPSO-FL method outperforms the compared VNAODV and LLA in packet delivery fraction. Because, collectively coordinated metrics such as bandwidth, node energy, and node mobility in finding candidate nodes in the PPSO-FL result in a higher packet delivery fraction. Due to reactive and any path routing for individual vehicles, the packet delivery fraction of VNAODV and LLA improves with increasing data packets. As a result, PPSO-FL outperforms VNAODV and LLA in candidate node selection and packet delivery fraction. The result shows that the PPSO-FL method maximises the packet delivery fraction by 9.84% more than VNAODV and 23.92% more than LLA.

Table 2 Performance analysis of packet delivery fraction

Data Packets	Packet Delivery Fraction (%)		
	PPSO-FL	VNAODV	LLA
8	89.35	78.29	65.32
16	91.48	83.38	70.23
24	93.25	86.15	74.19
32	88.49	78.39	65.28
40	90.21	81.11	68.37
48	93.17	85.07	72.14

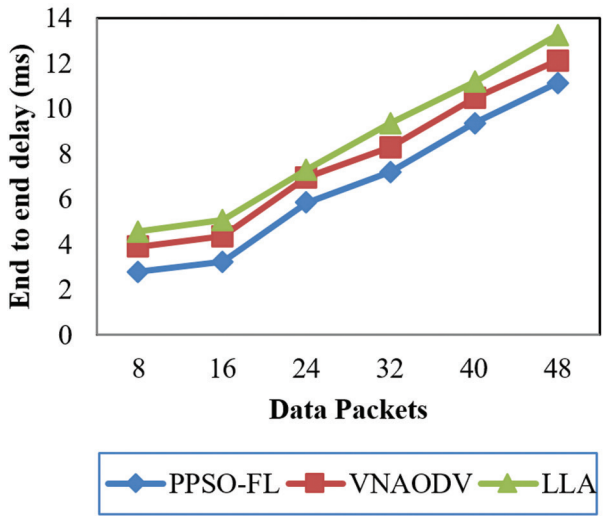

Fig. 7 Measure of end to end delay

Fig. 7 shows the end-to-end delay for different packets transmitted by 60 different nodes. When the speed and density of the data packet increase, the frequency topology changes also increase. Frequent route reconstruction increases control overhead, potentially increasing congestion rate and packet collisions. Fig. 7 shows that the PPSO-FL method effectively reduces end-to-end delay, particularly when the speed is high, and the size of data packets is small. The topology changes fast as the speed increases, and thus the size of data packets increases, increasing the end-to-end delay. However, compared to the existing VNAODV and LLA, PPSO-FL shows significant improvements. The VNAODV and LLA fail to incorporate the rate of bandwidth, node energy, and mobility in route selection, resulting in this improvement. They provide longer delays if the size of the data packet is large. The fuzzy-based candidate selection method is used in the PPSO-FL method to select the candidate nodes, reducing route rediscovery. As a result, the PPSO-FL method produces the lowest end-to-end delay by 21.34% compared to VNAODV and 35.60% compared to LLA, respectively.

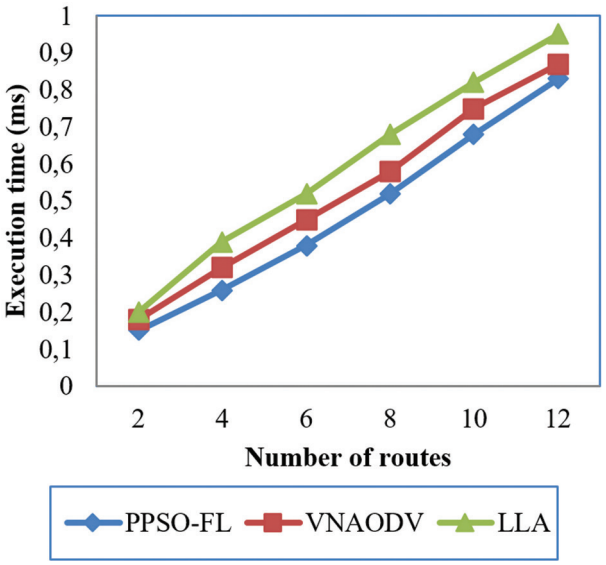

Fig. 8 Measure of execution time

In Fig. 8, we evaluate the execution time for routing using the three methods PPSO-FL, VNAODV, and LLA that presents the relationship between execution time and the number of routes identified. The results proved that packets routed through PPSO-FL require fewer candidate nodes to reach a destination than state-of-the-art routing protocols. The Position-based PSO that eliminates the dependence of parameters, 'ω, ac_1 *and* ac_2' with direction toward the destination in-network, results in better performance, reduces the execution time for routing using PPSO-FL by 14.69% compared to VNAODV and 30.99% compared to LLA.

5. CONCLUSION

In this paper, we have designed a Position Particle Swarm Optimization with Fuzzy Logic (PPSO-FL) method for VANETs, leveraging the collectively coordinated metrics instead of instantaneous velocity. Furthermore, when determining the candidate node, the proposed

method takes into account the maximum collective coordinated outcome. A practical solution is provided utilising position-based PSO based on the approach, ensuring optimal routing based on the converging characteristic of PSO. Because, packet delivery fraction is the essential element impacting routing efficiency of all parameters, precisely calculating this value is critical. We used updated positional values to remove the control coefficients, resulting in optimal routing that avoided the effects of rapid velocity changes. The simulation results show that, when compared to previous research, the suggested algorithm increases the packet delivery fraction for various numbers of routes and packets. The proposed model has a better performance in terms of execution time and end-to-end delay.

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Data collection protocols for wireless sensor networks

Review Paper

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Abstract *– Data collection in wireless sensor networks (WSNs) has a significant impact on the network's performance and lifetime. Recently, several data collection techniques that use mobile elements (MEs) have been recommended, especially techniques that focus on maximising data delivery. However, energy consumption and the time required for data collection are significant for many WSN applications, particularly real-time systems. In this paper, a review of data collection techniques is presented, providing a comparison between the maximum amount shortest path (MASP) and zone-based energy-aware (ZEAL) data collection protocols implemented in the NS-3 simulator. Finally, the study provides a suitable data collection strategy that satisfies the requirements of WSN applications in terms of data delivery, energy consumption, and the time required for data collection.*

Keywords*: wireless sensor networks, data collection, routing protocols, mobility*

1. INTRODUCTION

Wireless sensor networks (WSNs) were introduced in 1994. A WSN is an ad hoc network that collects data of the deployment area. WSNs are used in various applications, especially in environment monitoring applications [1].

WSNs consist of independent devices called sensors or nodes, of which there may be thousands in large-scale networks. Sensors have many components for processing, sensing, power supply, and other functions. The nodes in WSNs have limited resources for processing, energy, memory, and bandwidth. Therefore, it is important to use these resources wisely.

Sensors collect and process the environment's data and send it to their neighbouring nodes (intermediate nodes) to reach the destination (base station). According to sensor type, two types of networks can be distinguished: homogenous and heterogeneous WSNs. Homogenous WSNs consist of identical nodes in terms of their capabilities. Heterogeneous WSNs, in contrast, have more than one type of sensor [2]. Fig. 1. shows the structure of a WSN.

Data collection operations mainly consume network energy, so energy management is vital for prolonging a network's lifetime. Therefore, using an effective data collection strategy should be considered to enhance a WSN's efficiency.

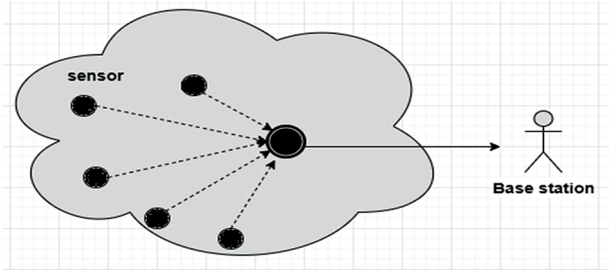

Fig. 1. Wireless sensor network

Many WSN designs distribute the energy consumption between the deployed sensors according to their locations and the location of the sink node (or its trajectory if it is a mobile data collector). In addition, they specify the periods in which the sensors are active or at standby to save energy.

Although the main goal of the data collection strategy is to collect the maximum amount of data, the time required for the data collection has a significant effect on energy consumption. This issue will be discussed in more detail in the following sections.

The structure of the rest of the paper is as follows. Section 2 presents the routing protocols in WSNs and provides their challenges. Section 3 presents the concepts of clustering in WSNs. Mobility and WSNs are introduced in Section 4. The data collection process in WSNs and the related mobility issues are discussed in Section 5. A review of the data collection studies is covered in Section 6. A detailed comparison between the maximum amount shortest path (MASP) and zone-based energy-aware (ZEAL) data collection protocols is given in Section 7. Finally, conclusions and future work are mentioned in Section 8.

2. ROUTING PROTOCOLS IN WSNS

Routing protocols are one of the most significant research areas in WSNs. Routing in WSNs faces some challenges that are a trade-off between responsiveness and efficiency. This balance must deal with limited communication capabilities and sensor suspension versus the overhead required to adapt to this situation. In a WSN, the total overheads are calculated primarily on the basis of bandwidth usage, energy consumption, and processing requirements for sensor nodes. A strategy for balancing these parameters is the basis for testing the routing efficiency.

Routing protocols in ad hoc networks can be divided into categories depending on the way the data are captured and the manner in which paths are estimated on the basis of the captured data. Routing protocols can be categorised as follows [3]:

2.1. PROACTIVE ROUTING

The proactive routing protocols require that the information is spread according to accurate routing tables. The sensing nodes set their routing tables before the sink nodes request the data. The routing tables are updated according to the network's topology structure.

The network's structure may be flat or hierarchical. In the flat type, the nodes send their data to reach the sink node through intermediate nodes using multi-hops. In contrast, in the hierarchical type, the network is organised in adjacent groups called clusters. Each node in a cluster sends its data to the cluster head to forward it to the sink node. The hierarchical type is often used in large-scale WSNs for saving energy. Clustering will be presented in detail in Section 3.

2.2. REACTIVE ROUTING

Reactive routing creates dynamic paths from the sensing nodes to the sink node according to the application's requirements. The routing path selection does not depend on the global information of the network or the routing tables. This type of routing usually involves flooding a discovery query. The use of flooding raises the number of messages through the network. As a result, the number of connections increases, which increases energy consumption. Therefore, it is vital to use a method for controlling the flooding process.

2.3. HYBRID ROUTING

In WSNs, many applications use a mix of reactive and proactive routing, which is called a hybrid routing protocol. Hybrid routing protocols rely on the network's architecture for stability and scalability in large-scale networks.

3. CLUSTERING AND WSNS

The communication process in a WSN is an essential factor in energy consumption. Numerous researchers are trying to find an efficient communication method to reduce energy consumption. They try to decrease the number of communication messages to decrease the total communication overload. One of the well-known models is clustering.

The clustering components are the following [4]:

- Sensor node: the essential component of a WSN. It has the capability of sensing and processing the data.
- Cluster head (CH): the coordinator for a selected group (cluster). The CH is responsible for many activities in the group, such as data collection and data transfer to the base station.
- Base station: the central node for data collection in a WSN. It is the ultimate source of data for the end-user of the network.
- Cluster: the network's structural unit that is used to facilitate communication in WSNs.

In the clustering model, the sensing nodes send their data to the cluster head in their region. The cluster heads, in turn, forward their data to the base station. Using this strategy achieves a reduction in energy consumption and the number of transmitted messages. Fig. 2. shows the components of the cluster model.

Clustering has many advantages: it helps transfer the data to the base station, decreases the number of intermediate nodes involved in the transmission, saves energy, supports network scalability, and reduces data transmission. However, the main problem occurs when one of the cluster heads is down because of energy depletion [4].

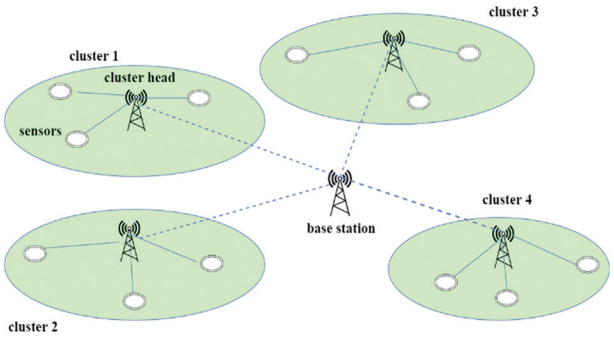

Fig. 2. Clustered sensor network

4. WSNS WITH MOBILITY

Many studies proposed mobility in the architecture of WSNs: mobility in sensing nodes or sink nodes or both. Using mobility can reduce the number of transferred messages and energy consumption.

Mobile wireless sensor networks (MWSNs) are different from the fixed WSNs. Incorporating navigation into network nodes can change many network features. The following features can be changed as a result of navigation [5, 6]:

- Localisation: In fixed sensor networks, the sensors are static as soon as they are deployed, so it is possible to obtain information about the location of the adjacent sensors. In MWSNs, the sensors move within the grid, so energy and transmission techniques are important for getting the location of the adjacent sensors.
- Network topology: Because of the continuous motion of the sensors, the routing tables are updated in each period. Note that most common WSN routing algorithms do not consider the dynamic changes in the routing tables used in MWSNs.
- Energy consumption: An MWSN requires dynamic motion between sensors, which consumes a large amount of energy. In the applications of WSNs, the energy consumption is taken care of by providing the nodes with a large source of power or recharging capability.
- Network sink: Most WSN types use a static sink node. However, in some cases, the sink can be mobile, as in an MWSN. This mobile sink node visits the sensor nodes to gather their data. Therefore, data collection techniques are different in an MWSN.
- Complexity: The algorithms used in an MWSN are more complex than those in a fixed WSN. The mobile sensor deployment mechanism is considered to be one of the biggest design challenges for the algorithms in MWSNs. In addition, a complicated node design is used in MWSNs.

The mobility approach provides many advantages in terms of connectivity, cost, reliability, and energy efficiency. However, using navigation in WSNs comes with many challenges that do not exist in fixed WSNs, such as connection discovery, perceived power management for mobility, reliable data transfer, and navigation control [6].

An MWSN contains two main components:

- Regular nodes, which acquire the environment data.
- Sink nodes, which receive the data from the other nodes.

The previous WSN-ME (mobile element) architecture is called homogeneous or flat. Otherwise, in some WSN-ME architectures, support nodes are used as an intermediate data collector or gateway. This WSN-ME architecture is called heterogeneous or tiered.

5. DATA COLLECTION IN MWSNS

Data collection is one of the most important research fields in WSNs. The sensors' energy is consumed mainly for data transmission through the network. Radio frequency (RF) shared broadcasting is responsible for up to 80% of the energy consumption, so many researchers are trying to reduce the number of transmitted messages.

The goal of the data collection protocol is to collect the maximum amount of data and reduce the data loss by considering energy consumption. Through effective data collection techniques, the performance and effectiveness of the network can be improved, thereby also prolonging the network's lifetime.

Traditional data collection protocols depend on collecting data directly from the sensing nodes or using intermediate nodes to forward the network's data to the sink node. The intermediate nodes utilise more energy than the other nodes and deplete faster. The traditional method is effective in data collection but has an impact on prolonging the network's lifetime, especially in large-scale networks. Additionally, these nodes are distributed randomly in a dynamic environment, so it is hard to use routing tables or to gather geographic information for each node.

The traditional protocols transfer huge messages, thereby consuming a lot of energy, so mobile data collectors (MDCs) have been introduced to solve these problems. The mobile collector moves on a pre-defined or random path to get the sensed data from the nodes within its communication range.

Mobility may be incorporated into the network's components. For example, the nodes may be moving, and the sink nodes may be static. This architecture is called a WSN-ME architecture with relocatable nodes. Conversely, the nodes may be static, and the sinks may be mobile. This architecture is called a WSN-ME architecture with MDCs, which use a mobile sink or mobile relay. The network can be regarded as a WSN-ME architecture when at least one of the components listed above is mobile [6].

Data collection in a WSN-ME architecture is different from the data collection operations in traditional WSNs (static networks). Several main phases are needed to collect the data in WSN-ME architectures. Below, these phases are described together with their requirements and challenges [6].

- Discovery protocols: These protocols are used to detect contacts as soon as the connection becomes available. Many different approaches exist. In mobility-independent protocols, the MEs can be recognised by their navigation style (scheduled rendezvous, on-demand, and asynchronous). With prior knowledge about the mobility of nodes, the sensors are in an inactive mode and are activated when the ME device is expected to contact a node. Asynchronous detection protocols are used to verify that the ME is within the range of the network nodes. In this case, messages are constantly emitted from the ME while the fixed sensors are set ready. When the ME is detected, the sensors start storing the communication time to prepare their routing table.
- Data transfer protocols: These protocols are designed to maximise the number of successfully transmitted messages from each node while minimising energy consumption. The MDC speed and the distance between the MDC and the sensors affect the data collection ratio.
- Routing to mobile elements: When the network density is sufficient, multiple paths may be allowed. Routing techniques with uncontrollable MEs can be classified into two classes. In horizontal (flat) routing, all nodes operate with identical mechanisms and roles. In proxy-based routing, several agents or gates are chosen from the sensor nodes, and these agents are considered the means of communication between static sensors and MEs.
- Motion control: The node's movements are either under control or uncontrollable. With uncontrollable navigation, the sensors are compatible with the path of the ME across the network. When navigating is controllable, the ME's movements can be designed to achieve specific objectives and to improve the performance standards. Mobility can be improved by selecting an efficient trajectory for the ME's movements and speed.

6. DATA COLLECTION METHODOLOGIES AND TECHNIQUES: AN OVERVIEW

In this section, a review of data collection methodologies and techniques in MWSN are presented with their structures and concepts. Additionally, some open research areas are mentioned for future work.

Nguyen et al. [7] presented compressive sensing for data collection in WSNs using mobile sensors distributed randomly in the network. These mobile sensors move randomly in any direction with different velocities but within their neighbours' transmission range to exchange their sensed data. The sensors execute rounds of movements to collect data about the current position. Finally, they are able to reconstruct the data about the sensing area. However, using more than one mobile sensor requires additional techniques to handle the coordination between the nodes.

The clustering mechanism is successful in maintaining energy resources for network activities. Many unbalanced aggregation algorithms have been proposed to overcome the issue of hotspots (using intermediate nodes in a traditional WSN). However, the energy depletion problem remains because the activities of the head of the cluster are closely related to its position in the network. Clustering in an MWSN involves an additional challenge: how to control the motion of the ME to access the cluster heads when the model does not depend on routing tables.

Gattani et al. [8] proposed a data collection algorithm that depends on compressive sensing using score-based load balancing. The sensed area is divided into clusters. Each cluster contains a head selected by the other nodes. The cluster head is selected from the two best nodes according to their remaining energy and the distance between them and the base station. The sensed data is compressed by compressive sensing in the cluster head and forwarded to the final destination. The network data is reconstructed from several measurements in the final destination. Through this model, the overall amount of transmitted data and energy consumption are reduced.

Du et al. [9] tried to overcome the memory limitation (or buffer-overflow) problem. The authors proposed a mobile-sink data collection approach that depends on heterogeneous sensors in which each sensor has its sampling rate, buffer size, and buffer-overflow time. The proposed algorithm divides the sensed area into groups (clusters). Each group contains a cluster head with buffer-overflow time. The buffer-overflow time is increased by adding a temporary cache to the cluster head as a deputy cluster head. Finally, they proposed an algorithm to determine a moving path to the mobile sink to reach the cluster head on time to prevent buffer-overflow problems.

Luo et al. [10] presented a two-tier data dissemination (TTDD) protocol that depends on building a grid-based structure. The grid structure consists of cells (squares) and crossing points (the intersections of the grid lines). In forwarding the data, the source sensor is considered a transit point that sends an announcement message to its four adjacent junctions, thereby reducing the spread of the network data by exploiting the location of the crossing points. For example, only the nearest node to the intersection will process the message. The repetitive publication spreads to the sensors and acts as a proxy to identify routing paths. The MDC begins the data collection process by sending a query message to its region.

The deployment points publish the query within the network and retrieve the network data from the nodes. In a TTDD protocol, it is assumed that the nodes' positions are known, and the protocol takes advantage of the geographical location of the nodes.

Kumar et al. [11] presented a scheme for data collection in WSNs with an integer linear formulation. The sensed area is divided into grids that contain many nodes with a random distribution. Each grid has a cache point to receive the sensed data from the sensors in the same grid. After that, an ME collects the data from the cache points. The actions in the scheme are split into two parts. First, find the cache points. Secondly, find the shortest path between the cache points, and use it as the ME's path.

Gao et al. [12] presented the maximum amount shortest path (MASP) protocol. The MASP protocol is a data collection strategy that uses a mobile sink moving along a constrained path. The sensors in the communication range of the sink are chosen as gateways to gather the data from the other nodes using multi-hop routing. Integer linear programming with a genetic algorithm decreases the transmission steps from the sensing nodes to their destination (a sub-sink node). The authors mentioned the bottleneck problem, which occurs when a set of proxies has many messages with a short contact time with the ME (the problem of hot spots). This problem is handled by allocating proxy nodes according to the length of the contact time to increase the throughput with minimum energy consumption. They use a two-phase data collection protocol, called ME discovery, and data gathering to implement this scheme. The MASP protocol operates with and supports the use of many MEs. By using the OMNET++ simulator, the authors show that this scheme performs better than the shortest path tree (SPT) method according to the amount of data collected and the energy consumption. The authors use three cycles in the discovery phase to identify the network topology and distribute the topology information to assign the members' nodes to their corresponding sub-sinks. Consequently, the data collection consumes overall a large amount of energy and time. Another issue is that the protocol depends on a synchronised transmission between the mobile sink and sub-sink nodes, thus requiring a perfectly synchronised clock between the nodes, which is not available in many systems.

Gallegos et al. [13] presented an implementation of the MASP routing protocol using a network simulator (NS-3). The authors show that the protocol uses three rounds (a mobile sink going back and forth to the beginning of its trajectory is called a round) to complete the data collection process. Their results show that the MASP routing protocol performs better in terms of energy consumption than the ad hoc on-demand distance vector (AODV) protocol.

Gallegos et al. [14] proposed an energy-aware data collection protocol (ZEAL) based on the MASP protocol. The protocol is based on dividing the environment into independent zones according to the movement path of the mobile sink. The mobile sink moves through a pre-defined trajectory to set routing zones and select sub-sink nodes. The mobile sink collects data from the sub-sinks that receive data from the sensors. After that, a communication time-slot assignment algorithm is used to assign the sub-sink nodes to the mobile sink to overcome the hot-spot issue. The mobile sink calculates the number of member nodes assigned to each sub-sink node according to their contact time. When the sub-sink nodes receive the number of nodes assigned to them, they send it to each member node to calculate the priority to select one sub-sink node and send their data to the targeted sub-sink. The mobile sink goes inside the network to collect the sensed data from the sub-sinks. In addition, the member nodes use duty cycling to reduce energy consumption. The authors presented an implementation of the protocol using the NS-3 simulator. The results show that the performance of the ZEAL protocol is better than that of the MASP protocol in terms of both energy consumption and packet delivery rate.

7. MASP AND ZEAL PROTOCOLS

In this section, the MASP [12] and ZEAL [14] protocols are compared in detail.

7.1. MAIN FEATURES

The MASP and ZEAL protocols use the following three types of nodes (Fig. 3.):

- Sink: a node that collects data from the sub-sink nodes.
- Sub-sink: a node that is within the communication range of a sink node and that is in direct connection with it.
- Member: a node that is not in direct connection with a sink and that uses sub-sink nodes as intermediate nodes.

The MASP and ZEAL protocols use random node deployment, hybrid routing protocols, and multi-hop communication modes. In addition, they can be applied in large-scale WSNs. Table 1 shows the different features of the ZEAL and MASP protocols in detail.

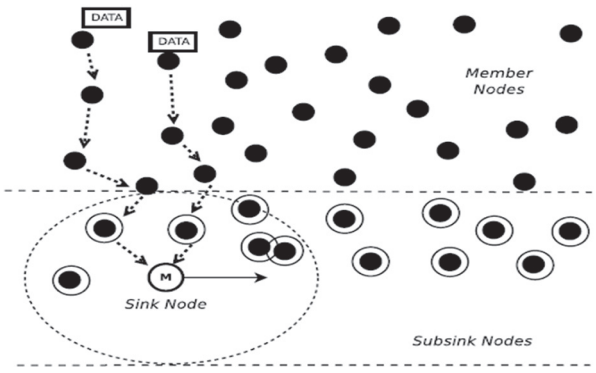

Fig. 3. Node types [14]

Table 1. Different features of the MASP and ZEAL protocols.

Feature	MASP	ZEAL
Routing type	Proactive	Hybrid
Number of cycles	3	2
Number and names of rounds	2 Discover, data collection	2 Setup, data collection
First phase	Assigning members to sub-sinks	Creating independent zones, populating routing, and assigning a sub-sink to each zone.
Second phase	Member nodes start collecting data from the monitoring area to send the data to the assigned sub-sink, and the sub-sink sends its data to the mobile sink	Member nodes start collecting data from their zone to send the data to the assigned sub-sink, and the sub-sink sends its data to the mobile sink
Method to assign sub-sinks	According to the length of the contact time	According to the number of zones
Methods to solve overlap in communication contact time	Minimum, shared, or optimally shared overlapping time	Minimum, shared, or selective time assignment
Method to assign member nodes to sub-sinks	A centralised heuristic solution based on a genetic algorithm	Member requirements in terms of number of hops
Zone partitioning	No	Yes, automatic
Data collection mechanism	Synchronised	Poll
Energy saving	No	Yes

The main discussion point is how the time required for the data collection operations affects the overall data collection performance in terms of data delivery and energy consumption.

In [12,14], the authors use the terms cycle and round with the same meaning. A cycle is defined as the tour of a mobile sink from the start point of the path to the end and back to the start point again.

According to this definition of a cycle, the total data collection time (T_{col}) is

$$T_{col}=N \times C_{time} \quad (1)$$

where N is the number of cycles and Ctime is the time for one cycle.

Gao et al. [12] presented the MASP protocol and proposed a data collection process that is completed within three cycles for ME discovery only, another cycle for the data collection process.

Gallegos et al. [13] presented an implementation of the MASP protocol using the NS-3 simulator and proposed that the data collection process can be achieved within three cycles.

Gallegos et al. [14] presented the ZEAL protocol. The data collection process can be achieved within two cycles (one cycle for setting up the network and another cycle for the data collection process). However, the authors use three cycles (one cycle for setting up the network and two cycles for data collection) in the simulation's implementation.

In the next section, the MASP and ZEAL protocols are implemented with a well-known simulator (NS-3) to show the effect of the time-saving method on data delivery and energy consumption.

7.3. IMPLEMENTATIONS AND EVALUATION OF THE RESULTS

The MASP and ZEAL protocols are implemented in the NS-3 simulator, using randomly distributed nodes. The network area is assumed to be a rectangle (400 x 200 m). The mobile sink moves on a constrained path at the bottom of the rectangle. The initial energy of the nodes is 3000 J with a 52-m communication range. The speed of the mobile sink is 5 m/s. The data transmission rate from a sub-sink to a mobile sink is 20000 bps; the data transmission rate from a member node to a sub-sink is 8232 bps.

In this section, the data collection performance of the MASP protocol (with three cycles) and that of the ZEAL protocol (with two and three cycles) is compared in terms of

- Data delivery (Data Del): the percentage of the delivered data (the sink node) relative to the total number of nodes.
- Average of the remaining energy (Avg Re Eng): the percentage of the average remaining energy relative to the initial energy.

According to Eq. (1), the number of cycles affects the total data collection time. In the data collection process, the ZEAL protocol saves one movement cycle of the mobile sink, so the ZEAL protocol saves 33% of the total time needed for the data collection. This saving is highly relevant in many WSN applications, especially in emergency applications.

Figs. 4 and 5 show that the ZEAL protocol with two cycles is better in saving energy than the MASP and ZEAL protocols with three cycles. This saving occurs by reducing the time needed for data collection and the number of transmitted messages. Therefore, if the objective of a WSN application is saving energy, then it is better to use the ZEAL protocol with two cycles only.

In contrast, the MASP and ZEAL protocols with three cycles are better in data delivery than the ZEAL protocol with two cycles.

Figs. 4 and 5 show the trade-off between data delivery and the average reaming energy, indicating that maximising the data delivery implies more energy consumption. In contrast, increasing the time of data collection improves the data delivery.

Fig. 6 shows that the MASP protocol is better than the ZEAL protocol in data delivery with an increasing number of nodes. The results show that the MASP protocol is more suitable for large-scale networks.

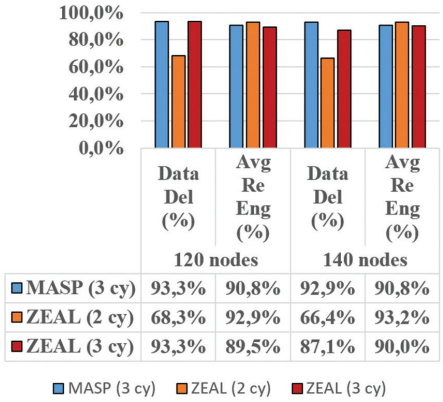

Fig. 4. MASP and ZEAL with 120 or 140 nodes

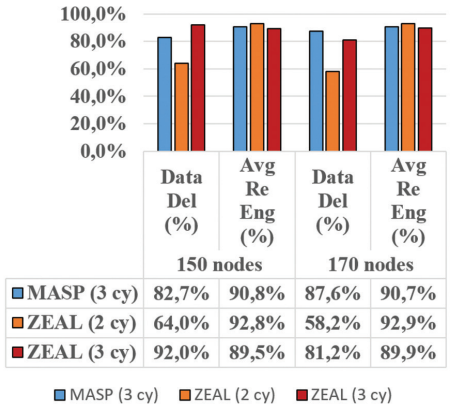

Fig. 5. MASP and ZEAL with 150 or 170 nodes

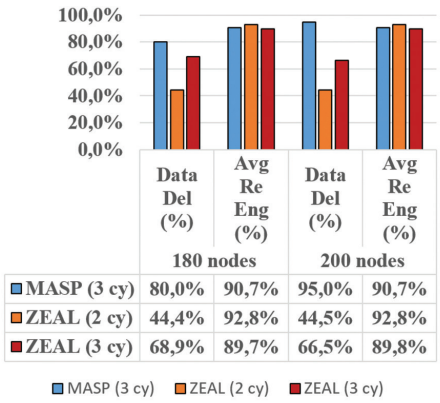

Fig. 6. MASP and ZEAL with 180 or 200 nodes

8. CONCLUSION AND FUTURE WORK

Using mobility in data collection improves the energy consumption and affects the network's lifetime. However, mobility causes new challenges, such as routing the mobile sink, contact discovery, data transfer, and motion control.

Recently, zone-based protocols have proved to be efficient in the data collection process while minimising energy consumption.

This study presented a detailed comparison between the MASP and ZEAL protocols, which will be helpful for researchers in selecting the most suitable protocol for a WSN application. The results indicated that the ZEAL protocol with two cycles saved 33% of the total time needed for the data collection in the MASP protocol, therefore, it is suitable for emergency applications.

However, if time is not critical, the MASP protocol with three cycles can be used to maximise the data delivery. In addition, the results showed that the MASP protocol is more suitable for large-scale networks.

Future work will be related to developing zone-based protocols using artificial intelligence features to improve the contact discovery and data transfer methods.

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Implementation of MQTT Protocol in Health Care Based on IoT Systems: A Study

Case Study

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Abstract *– Internet of things IoT systems have become one of the most promising technologies in all fields. Data transmission is one of the important aspects, and the tendency to messaging protocols is an important aspect of IoT systems. One of these most important protocols is MQTT. This protocol depends on the Publish/Subscribe model, and it is a lightweight protocol. Reliability, simplicity, quality of service levels, and being Resource-constrained make MQTT common in the IoT industry. This paper designed an IoT device that consists of the sensor MLX 90614 non-contact IR Temperature connected to a development board (Node MCU ESP8266). A person's temperature is one of the important vital signs. This system measures human temperature values and transmits the measured values to the Mosquitto broker by using the MQTT protocol in real-time. The technology used is Wi-Fi. The person or the doctor can read the patient's temperature remotely through a program (Flutter Android Client) representing the subscriber. Also, MQTT protocol control packets of the system were analyzed using Wireshark. The three levels of QoS were used in subscriber clients to compare the throughput. The results indicate that QoS2 is more reliable and offers more throughput but more delay. The results also show that the average round trip time (RTT) of the MQTT protocol is five milliseconds which means optimal performance for IoT applications.*

Keywords*: IoT, MQTT, Publish/Subscribe, Broker, QoS, MLX90614, NodeMCU ESP8266*

1. INTRODUCTION

The IoT needs a specific environment characterized by intelligence, as the Internet of Things device is any device that can be connected to the internet to collect data by sensors, process it, and send it over the internet to its specified endpoints. Fig. 1 shows the stages of dealing with data in IoT systems. IoT technology can connect any device to the internet in real-time at any time and from anywhere to control and analyze it [1, 2]. The IoT faces many issues that need to be addressed to properly implement it, including security and privacy and scalability, interoperability, and data management [3]. These are in addition to the lack of homogeneity of components with each other [4]. The application layer protocols of IoT responsible for transmitting data are important aspects. In the transmission of IoT, sensor data must use lightweight protocols and show bandwidth efficiency as these are fundamental features of the IoT. Moreover, it must show the efficiency of energy and capability of working with minimal hardware resources (like main memory and power supply) [5]. Internet access needs application protocols through UDP/IP or TCP/IP [6]. The protocols used in Internet of Things systems are as follows: MQTT (Message Queue Telemetry Transport), HTTP (HyperText Transport Protocol), AMQP (Advanced Message Queuing Protocol), COAP (Constrained Application Protocol), DDS (Data Distribution Service), XMPP (Extensible Messaging and Presence Protocol)[7]. One of the most important protocols used to transfer data in IoT systems is MQTT [8] which appeared in 1999 [9]. It was developed by Andy Stanford-Clark of IBM and Arlen Nipper of Arcom Control Systems [10]. MQTT protocol is considered OASIS standard [11] and M2M communication [12]. The publish/subscribe model used in the MQTT protocol makes it appropriate for M2M messaging [13]. One of the most important factors determining these M2M communications' performance is the messaging protocols designed for internet of things applications. The MQTT protocol uses default port 1883 and uses TCP/IP as transport [12]. MQTT uses Transport Layer Security/Secure Sockets Layer (SSL/TLS) as security [14]. It is considered one of the lightweight protocols used in devices with limited resources such as the IoT [12]. This protocol reduces the overhead costs and provides high communication efficiency for the internet of things as

it relies on "name-based routing" [6]. MQTT communication has two kinds of agents: the first is MQTT clients, and another is the broker of MQTT. The protocol-transmitted information is known as the application message. The clients of MQTT refer to the objects or devices connected to the internet that exchange messages or communication through MQTT. The clients of MQTT are known as subscribers and publishers. MQTT transfers the data from source (Publisher) to destination (Subscriber) through the broker. In MQTT, clients (or publisher and subscriber) do not require to cognize the identity of each other. Using an address named Topic, each message of data is published. A publisher can forward the application message while the subscriber can demand that application message to obtain its data. MQTT clients can be any device like a mobile, a sensor, Etc. The broker lets the various clients communicate with each other. It transmits and acknowledges the application messages between various clients connected to it. Fig. 2 shows the Publish/Subscribe model of the MQTT protocol.

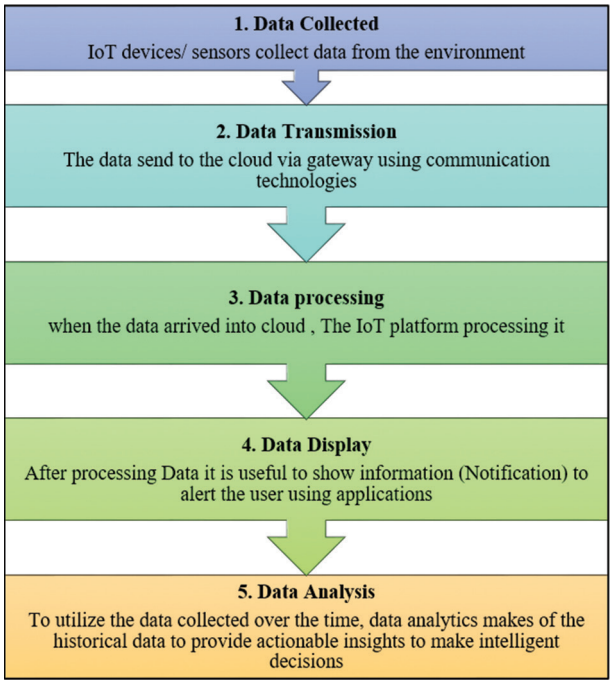

Fig. 1. The Stages of Dealing With Data In IoT Systems

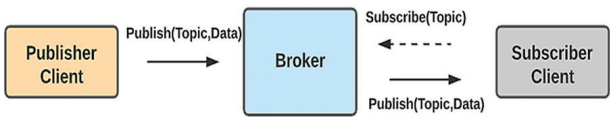

Fig. 2. Publish/Subscribe model of MQTT Protocol

Another prevalent protocol in web communication is HTTP. It utilizes a request/response model. This protocol is heavyweight, and it is a text protocol. This means that it sends massive size messages with high overhead. Instead of topics, HTTP utilizes the URI (Universal Resource Identifier). The server transmits data through URI, and the client receives it through the specific URI. Because HTTP is a text protocol, headers and payloads are determined by the programming technique or web server. The CoAP protocol, however, is an M2M and lightweight protocol. Like HTTP, the CoAP uses URI to send and receive data. It uses a request/response model. CoAP is a binary, like MQTT protocol which means that it needs 4 bytes fixed header and a small message of payloads up to a maximum size that varies depending on the programming technique or web server [15]. Table 1. shows the essential features and compares among MQTT, CoAP, and HTTP.

Table 1. Comparison among MQTT, CoAP, and HTTP

Protocol	MQTT	CoAP	HTTP
Designed by	IBM	IETF	IETF/ W3C
Messaging Model	Publish/ Subscribe	Request/Response	Request/ Response
Encoding Format	binary	binary	text
Transport Protocol	TCP	UDP	TCP
Hider Size	2 byte	4 byte	undefined
Security	TLS/SSL	DTLS, IPSec	TLS/SSL
Default Port	1883 (TCP Port) 8883 (TLS/SSL)	5683 (UDP Port) 5684 (DLTS)	80 (TCP Port) 443 (TLS/SSL)
QoS Reliability	At most once QoS 0, At least once QoS 1, Exactly once QoS 2	Confirmable Message Or Non-confirmable Message	Limited (via TCP)

In this paper, the body temperature data were collected using MLX90614 sensor as a publisher then sent to Mosquttio that uses as a broker by specific topic. Node MCU ESP8266 development board uses the technique Wi-Fi to transfer data. At the same time, a client was implemented using flutter. By the same topic, the client (doctor or person) subscribes to the broker to get the temperature value of the human in real-time. In addition, capture for the packets of MQTT was performed and analyzed it using Wireshark.

2. RELATED WORK

The MQTT protocol has been studied by many researchers. In this section, the most recent studies on this protocol are reviewed. The first direction relates to the implementation of the MQTT protocol in healthcare. The second direction is related to the study of the MQTT protocol, its analysis, and comparison with other protocols used in the fields of Internet of Things systems.

Sarierao and Prakasarao have been implemented a healthcare monitoring system using the MQTT protocol. The architecture of the Smart Healthcare System consists of microcontroller ESP32 using MQTT protocol. The sensors are used pulse rate, temperature sensor, spo2 sensor, and body movement sensor. This

healthcare system allows the doctor to remotely view a patient's vital signs on a web page and mobile app in real-time. All the doctor needs are internet access [16].

Another paper in the healthcare system has been implemented titled Smart Health Care System using IoT. It was used Node MCU ESP8266 with connecting sensors detecting (Heart Rate, Temperature, Fall Detection, and Step-Counter) and sends this data to a remote server through Wi-Fi using MQTT protocol. Heart rate: The device can be used to keep track of a person's heart rate. When the minimum threshold is reached, an individual can be automatically notified by doctors and family members. Using this device can save Millions of lives. Step counter: The device tracks the number of steps taken by the user so that he can exercise regularly. It also helps in calculating the number of calories in addition to knowing the body temperature and detecting the patient's fall [17].

The patient's vital signs monitoring system (heart rate and blood oxygen level) was designed using MAX30100 SPO2 sensor and connected to the ESP32 microcontroller using MQTT protocol to send these signs to be monitored via phone or computer. As a consequence of the publication Monitoring, vital signs of human hear based on IoT [18], the MQTT protocol is appropriate in health care applications for real-time monitoring of vital signs. Finally, on this part, Priyamvadaa suggested a utility to develop real-time body temperature readings using the MQTT protocol in healthcare. According to the results obtained, the researcher concluded that the MQTT protocol provides high data portability also energy efficiency, security, scalability, and reliability [19].

In the other direction, the protocol is covered and surveyed. It was explained the most importance of MQTT protocol in IoT, MQTT architecture, and existing problems in MQTT such as message expiry, security, ordering, and priority. Furthermore, the number of MQTT brokers was mentioned, with each having its own set of restrictions and none of them implementing data priority or future advancements for this protocol [20].

In another article, the architecture of the MQTT protocol is explored, as well as QoS levels, message format, and MQTT's scope. MQTT is essentially a binary data transfer protocol that supports a wide range of communication technologies. Its goal is to create a communication system that uses as little bandwidth as possible. MQTT uses the TCP protocol for transport and communicates over IP [12].

Another research detailed the MQTT protocol's architecture, QoS levels, message format, and MQTT scope. MQTT is primarily a binary data conduit that allows for a variety of communication methods. It's intended to provide a communications system with the least amount of bandwidth requirements. The MQTT protocol has been defined and compared to other IoT message protocols, such as CoAP, for transport. In addition, there have been tools available to aid in the execution of practical experiments and simulations. Experiments were performed to observe the communication delay between both MQTT and CoAP according to the results obtained. The QoS0 level of MQTT showed a lower delay than CoAP. Finally, the challenges and open issues in this field are examined [21].

In addition, it was introduced the various M2M communications protocols such as MQTT, CoAP, and AMQP that being used over the previous 20 years. The most widely used M2M/IoT protocol, MQTT, has been improving. The protocol was examined some of the most relevant research papers in the current literature reviews to highlight the key characteristics, benefits, and limits of this protocol and MQTT broker implementations concerning comparison to alternative IoT protocols. The results were presented findings of the current usage of MQTT and the areas of its application using different comparison tables and graphs. It arrived that an in-depth comparison of the characteristics of many brokers and clients libraries of MQTT in several taxonomy categories were utilized to enable the researchers and the users to choose implementation of MQTT based on the needs and appropriateness [22].

Finally, the MQTT protocol-based applications in IoT systems are addressed, and methods for controlling access and organizing data exchange across MQTT protocol contexts are proposed. According to the user's preferences and authorization policies, it was offered the framework of access control to manage data sharing across environments of MQTT [23].

3. USING MQTT PROTOCOL TO SENDING DATA TO THE CLOUD

MQTT stands for Message Queuing Telemetry Transport. It is considered a lightweight protocol, and it uses a server called a broker. The client(Publisher) sends the data as a message to the broker using a specific subject called a topic, indicating the data category. More than one client can receive the message from the broker via the same specified topic. Figure 3 shows the network of intercommunication using the MQTT protocol.

1. Message

A message is the basic unit of MQTT protocol communication; it contains basic information called the "topic" that constitutes the data exchanged between devices through the broker.

2. Topic

The topic is the basic information for determining the message to be sent and received. The structure of the topic is determined in the form of a hierarchy separated by a slash (/). The topic must always be specified when sending the message or when subscribing to receive it. Publisher client (sensor) publishes data with its topic, subscriber clients who want to receive it can assign the needed topic and receive the data [24].

3. Publish/Subscribe Paradigm

The publish/subscribe paradigm (or pub/sub) is an alternative to conventional client-server architecture. The publisher client and subscriber client never communicate directly with each other. Communication takes place via a third component called the broker. Several dimensions separate the publisher of the message from the subscriber, and they are as follows:

- Space decoupling: The publisher and the subscriber do not need to cognize each other (for instance: no interchange of IP address).
- Time decoupling: The publisher and the subscriber are not required to work at the same time.
- Synchronization decoupling: during receiving or publishing, operations do not need to be interrupted.

4. Broker

The broker represents the communication node between the publisher and the subscriber. It filters and organizes all arriving messages then distributes them accurately to subscribers using a specific topic interested in it [25]. There are many open-source brokers, the most important of which are Mosquito, Hive MQ, and Mosca. They differ in specifications and functions that must be taken into consideration in advance.

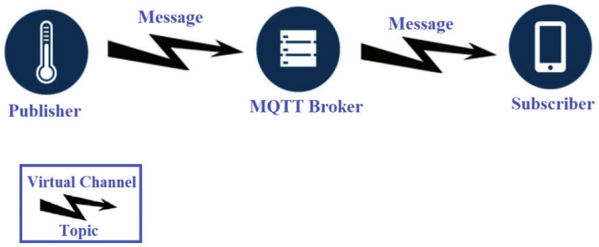

Fig. 3. The network for intercommunication using MQTT Protocol

4. QUALITY OF SERVICE QOS LEVELS IN MQTT PROTOCOL

The MQTT is an asynchronous protocol whose paradigm is based on Publish/Subscribe model. It flows through TCP/IP, connecting large numbers of control devices and remote sensors [26]. Devices are allowed to exchange data using a message broker. The broker of MQTT sends the message data to the subscribed clients and forwards, stores, prioritizes, filters, and publishes requests from the publisher client to the subscriber client. The chosen quality of service QoS level relies on the system. For example, suppose the system requires a constant data transfer. In that case, MQTT adapts QoS2 to deliver data even if there is a delay of time [27]. MQTT offers three levels of QoS [28]:

1. (QoS 0) --- At-most once. It is the simplest, fastest, and most unreliable level of QoS where the message data is transmitted to the subscriber client at-most-once (one time only). It is not saved or stored. Also, the publisher client does not receive any confirmation or information about delivering the message (no need to be acknowledged). If the subscriber client does not have a network connection or if the publisher is down or unable to receive the message, the packet is lost. The probability of repeated messages does not exist. The expression "fire and forget" describes (At-most once) QoS 0 level.

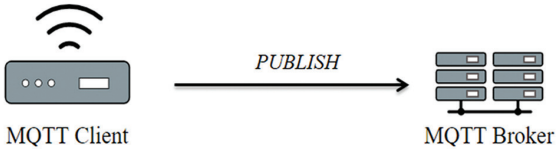

Fig. 4. Quality of Service (QoS0)

2. (QoS 1) --- At least once. The message of data is transmitted to the subscriber client At least once. An acknowledgment packet is used at this level of QoS. The publisher must use DUP flag for the duplicated data messages. The Publishing with QoS of level 1 needs two messages. The publisher publishes a data message to the subscriber if the publisher does not receive Acknowledgment from the subscriber. QoS keeps publishing the message until it receives the acknowledgment packet (PUBACK).

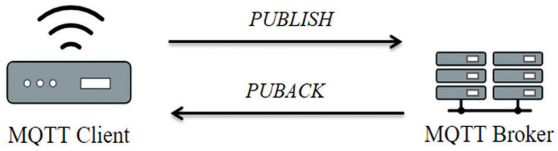

Fig. 5. Quality of Service (QoS1)

3. (QoS 2) --- Exactly once. QoS 2 is used to guarantee the data message delivery and to ensure safety. This level is the slowest as it needs four messages. While posting the message, two rounds of transition are utilized. The message must be stored to be processed by the publisher and the subscriber. In the first round, the publishing customer transmits a message of data to the subscriber client then waits for acknowledgment from the subscriber the message of data has been saved. If an acknowledgment is not received, the publisher sends the message until it receives the acknowledgment that message has been received. After that, the second round begins; the publisher sends PUBREL to inform the subscriber that the message can be processed and waits for an acknowledgment PUBREL of receipt from the subscriber and then deletes the message.

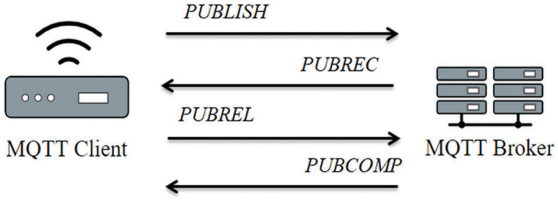

Fig. 6. Quality of Service (QoS2)

5. MQTT PROTOCOL FEATURES

Several points distinguish the MQTT protocol and make it suitable for IoT applications [29], including:

- It supports three levels of QoS to ensure message reliability.
- It uses bandwidth efficiently by packet agnostic, and it has a small overhead.
- The data is binary.
- The publish/subscribe method has capabilities like M2M communication. This technique also allows bi-directional communication.
- The communications are asynchronous.
- Anytime, it can publish/subscribe messages.
- It is suitable for limited-resource devices such as sensors for IoT systems.

6. SYSTEM DESIGN AND IMPLEMENTATION DETAILS

Hardware System Requirements:

1. Node MCU ESP 8266 development board
2. MLX 90614 Non-contact Temperature Sensor
3. Male to Male wires and USB Cable
4. Laptop

Software System Requirements:

1. Android Emulator in Flutter to execute Client
2. Arduino IDE
3. Mosquitto Broker
4. Wireshark to Capture Packets of MQTT Protocol

Table 4. MQTT Parameters

Parameter Used	
Broker	Mosquitto
Topic	Capture/Temperature
Port	1883
Subscriber	MQTT Client in Flutter

The design of the system is shown in Figure 7. The system consists of a sensor to measure the value of temperature in humans (MLX90614). This sensor which uses infrared (IR) and is non-contact, is connected to a Node MCU ESP8266 low-cost development board. Table 6 shows some specifications of Node MCU ESP8266 that distinguish it from other systems and make ESP8266 suitable for IoT projects due to its small size and its use of a full-stack of TCP/IP. ESP8266 accesses the internet through the router by using Wi-Fi technology and utilizing MQTT protocol. This system is designed to measure the human temperature as the measured data (temperature) is sent to the server (Mosquitto Broker [30]) by a topic that has been determined (Capture/Temperature). The person or doctor who monitors the patient's condition can see the measurement results in real-time from anywhere. The measured data is also stored in the server so that the results are saved as a database to be displayed again to check the patient's temperature at any time. In Table 5, we mention the properties of the sensor used MLX90614 while Table 6, specifications of Node MCU ESP8266.

Table 5. The Characteristics of MLX90614 Sensor

Operating Voltage	3v to 5v
Supply Current	1.5 mA
Range of Object Temperature	-70° C to 382.2°C
Range of Ambient Temperature	-40° C to 125°C
Accuracy	0.02°C
The distance among object and sensor	2cm to 5cm (approx.)

Table 6. The Specifications of Node MCU ESP8266

Microcontroller	32-bit Tensilica RISC CPU Xtensa LX106
Operating voltage	3.3 V
Wi-Fi	802.11 b/g/n
Clock speed	80 MHZ-160MHZ
Analog Input	1 pin
Digital I/O	16 pins

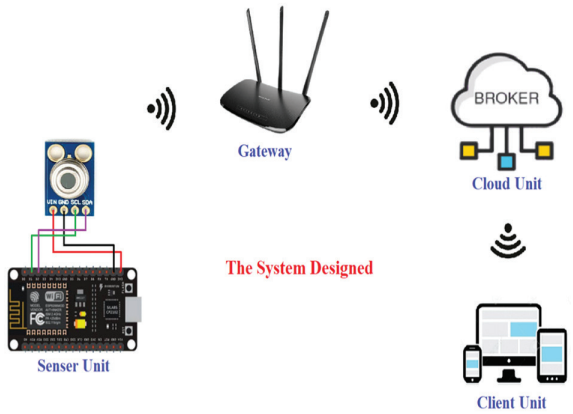

Fig. 7. The design of the system using the MQTT Protocol

7. CAPTURE MQTT CONTROL PACKETS USING WIRESHARK

The communication of MQTT protocol is the procedure of exchanging a series of control packets of MQTT [31]. This section explains the format of control packets for MQTT by capturing them using Wireshark. The control packet of MQTT consists of three parts, in the following order:

1. Fixed header: exists in all the control packets
2. Variable header: exists in some kinds of control packets
3. Payload: Also found in some control packets of MQTT

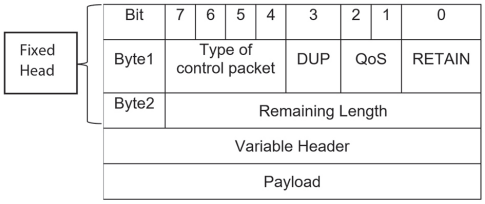

Fig. 8. Format of MQTT control packet

There are 14 kinds of MQTT control packets, and they are as follow:

1. CONNECT The first packet sent by the publisher client to the server after establishing the network through the client's communication with the server.

2. CONNACK: It is the acknowledgment of receipt of the communication packet sent by the server to confirm receipt of the connection packet, as it is the first packet by the server. If the time to receive this packet is exceeded, the customer will close the network connection.

3. PUBLISH: It is the packet that the publisher client and server can send to transfer data (application message).

4. PUBACK: It is an acknowledgment packet of PUBLISH packet with QoS level.

5. PUBREC: The response packet to the PUBLISH packet with the second level of quality of service (QoS 2).

6. PUBREL: It is a response packet to the PUBREC packet.

7. PUBCOMP: It is a response packet to the PUBREL packet.

8. SUBSCRIBE: The subscriber sends a subscribe packet using a specific subject assigned to obtain the application message.

9. SUBACK: It is an acknowledgment and processing packet for the SUBSCRIBE packet.

10. UNSUBSCRIBE: This packet sent by a subscriber to unsubscribe in topic

11. UNSUBACK: It is an acknowledgment packet for accessing an unsubscribe packet.

12. PINGREQ: Sending this packet determines if the client is alive.

13. PINGRESP: sending this packet determines if the server is alive. The server sends it to respond to the PINGREQ packet.

14. DISCONNECT: It is sent as the last packet to the server as it indicates a disconnection for the client.

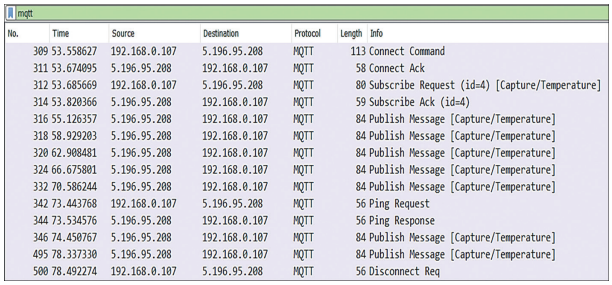

Fig. 9. Capture MQTT packets using Wireshark

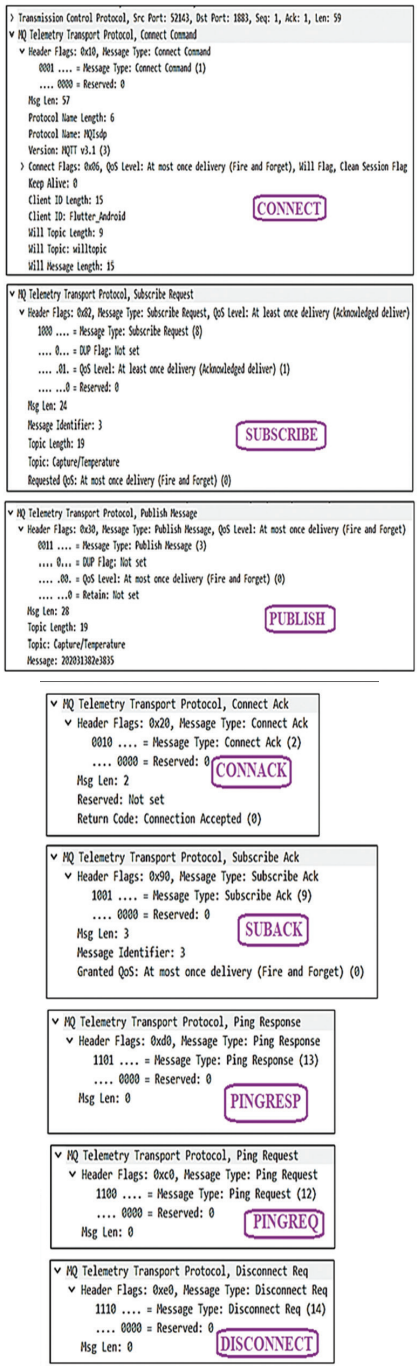

Fig. 10. MQTT control packets type using Wireshark

8. RESULTS AND DISCUSSION

The system was connected using MQTT protocol and was used to measure the human temperature. As the sensor senses the temperature, the readings, which represent the data, are published to the broker using a specific topic (Capture/Temperature) and picked up by a Mosquitto broker, which was chosen because it is open-source. The subscriber client has been implemented using flutter (software development) that the client can operate on the Android or Apple system. Fig. 11 shows the practical

connection of the Internet of Things (IoT) system, Fig. 12 shows serial monitors displaying the readings of temperature using QoS1 to publish data, while Fig.

13 shows the temperature readings in real-time using the MQTT BOX tool. The real-time human temperature reading was obtained using an Android Emulator that subscribes to the specific topic, as shown in Fig. 14.

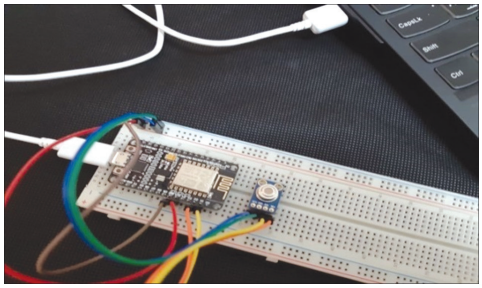

Fig. 11. IoT system (practical connection) NodeMCU ESP8266 with MLX90614 sensor

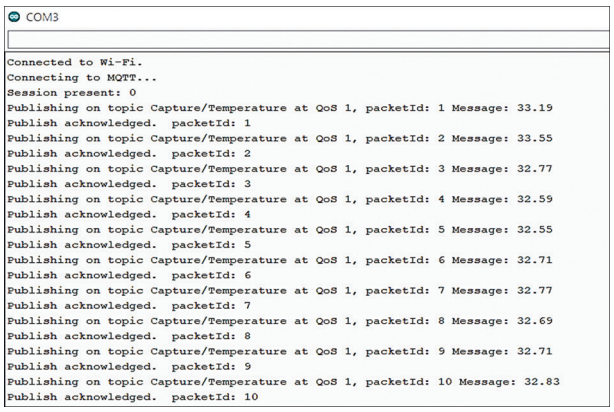

Fig. 12. The results of temperature on the serial monitor

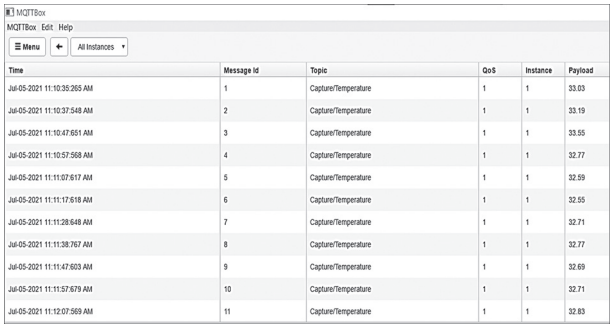

Fig. 13. The temperature in real-time using MQTTBox

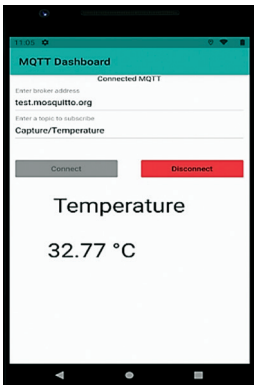

Fig. 14. Flutter Android Client

We noticed a quick response when subscribing to the specific topic using Wireshark, as shown in Fig. 15, which means that MQTT protocol has low overhead and provides high communication efficiency for the IoT system because it relies on "name-based routing". The feature of TCP Steam Graph, which exists in Wireshark, provides a whole record for RTT of each packet. RTT is the time needed for sending a packet and receiving acknowledgment packets. In a test of the duration of time in which RTT is ranged from 0 msec to 10 msec, the packets were captured between 1070-1110 sec, as shown in Fig. 16 and Fig. 17. The communication network speed uses the I/O graph of Wireshark, and the data were obtained at the three levels of QoS. Fig. 18 shows the detailed waveform of the bytes per sec for 100 sec. The throughput of this network means that the number of MQTT packets was successfully received. The results show that the highest level of QoS2 is more reliable and has higher throughput due to a 4-way handshake mechanism. MQTT protocol is distinguished from other protocols like HTTP and CoAP. It creates better packets and requires less time for transmission, even though CoAP is a UDP protocol [6] [29].

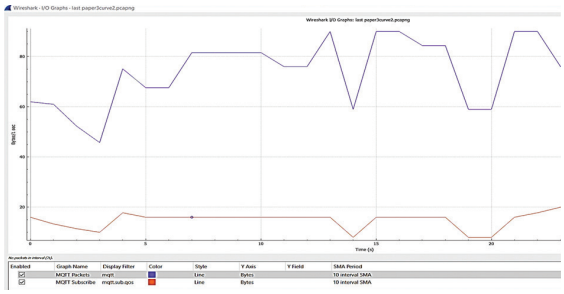

Fig. 15. The response when subscribing in the client

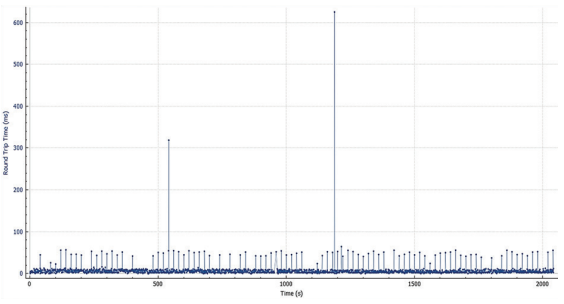

Fig. 16. RTT of the MQTT packets captured using Wireshark for 2000 sec.

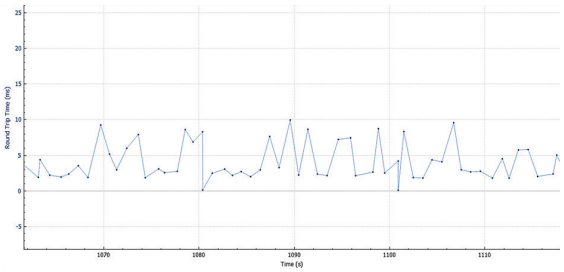

Fig. 17. RTT of the MQTT packets captured during 1070 sec - 1110 sec

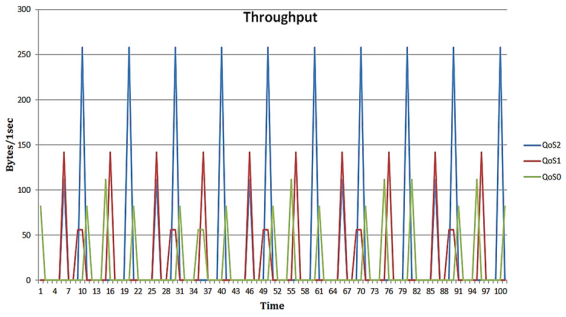

Fig. 18. Throughput for QoS levels

9. CONCLUSION AND FUTURE WORK

In this article, we suggested a system for monitoring the temperature of humans using the MQTT protocol in real-time as an IoT system can read the temperature from anywhere. The application that was implemented uses flutter and can be downloaded on Android and Apple systems. It was concluded that the protocol is a lightweight protocol that provides a high network connection and provides three levels of QoS to ensure reliability. The QoS2 is more reliable, and throughput but requires more time. The average RTT for the packets is approximately 5 msec, which could be considered the optimal response time for IoT applications. Future work can be aim is to expand and develop the system by introducing other sensors to measure the oxygen level and heart rate of patients using the MQTT protocol. Also, this system can be implemented with other Internet protocols such as CoAP and HTTP, and a comparison can be made between them in terms of performance.

10. ACKNOWLEDGEMENTS

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Effect of temperature in electrical magnitudes of LED and HPS luminaires

Case Study

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Abstract *– Temperature effects on luminaires is usually referred to light output, that is luminaire efficiency. However, the effect on electrical magnitudes as power, current and third current harmonic is not widely studied. One major technology, Light-emitting-diode (LED) is fast replacing the other types of lighting all over the world, this opens the interrogate of how is temperature affecting LED luminaires development and how different is this effect compared to other technologies. This paper analyses these effects on LED luminaires of different wattage and one high pressure SODIUM luminaire. Luminaires were measure in two different environments, the first stage with a constant temperature-controlled system (±1°C) and the second one without a temperature-controlled system. The tests were performed on three samples of LED luminaires with different power ratings and one sample of SODIUM luminaire. It was found that the third current harmonic is directly related to temperature while power and current are inversely related.*

Keywords*: LED, SODIUM, temperature dependency, current, 3rd current harmonic, measurement*

1. INTRODUCTION

Light-emitting-diode (LED) lighting is a growing technology that is being installed across the world, replacing some conventional technologies as high intensity discharge (HID) and compact fluorescent lamps (CFLs) [1]. While CFLs are used in domestic application, the High-pressure sodium (HPS, SODIUM) lamps are particularly suited to outdoor lighting and use on streets and highways.

LED lighting is a viable solution for many applications due to high energy efficiency and long life [2]. Its applications vary from industrial and commercial lighting to outdoor and public illumination, but while its diverse applications and strengths increase every day there is a significant disadvantage that must be taken into account, decreased performance with increased temperature [3].

LED luminaires operate at relatively high electrical input power, which requires good thermal management [4]. This may mean higher maintenance costs for LED technology; however, this technology is not the only one who seems affected by temperature. Discharge lamps are generally sensitive to outside temperature [5] and according to their constructive characteristics they will be more or less affected.

LEDs also require a constant current source from a low-DC voltage source obtained from the AC mains [6]. LED driver is the one who converts the input AC voltage of the utility grid into low DC voltage which is compatible with the LED and regulates the flow of DC current through the LED to control the extent of illumination [7].

Junction temperature, which refers to the temperature of active region in LEDs, is an important parameter. It in-

fluences the performances of LEDs, such as efficiency, output power, reliability, peak wavelength shift, and spectral width [8]. Increase in LED die junction temperature, due to power dissipation or changes in ambient temperature, significantly impacts its light output as well as peak wavelength. Therefore, thermal effects on LED behavior must be considered and LED junction temperature must be maintained below the maximum specified limit [9].

Performance characteristics of LED light sources are specified for a rated current and for a specific LED die junction temperature (ex. T_j = 85 °C). Since most LEDs operate at environment temperatures above or less to 25 °C, reference values and the light output should be based on the anticipated operating temperatures [10].

Higher ambient temperature leads to higher junction temperatures [11]. The ambient temperature and the drive current both affect the junction temperature of LED [12]. Higher LED die junction temperatures, resulting from increased power dissipation or changes in ambient temperature, can have a significant effect on light output [10].

As indicated in [12], as junction temperature increases LED's current decreases, which in turn cause decrease in light output.

The effect of temperature and current on luminous efficiency of high-power LED is analyzed in [13]. Their measurements were done with a high precision constant current, and a voltage DC stabilizer supplied the power of LED. The current-voltage characteristics were obtained with the analyzer and the luminous efficiency values at the temperature from 20 °C to 80 °C and the current from 10 mA to 350 mA was measured with the analyzer as well. When the drive current is 10 mA; the efficiency at 80 °C is 12.5 % lower than the efficiency at 20 °C. When the drive current is 305 mA, the efficiency at 80 °C is just 6 % lower than of 20 °C, concluding that the changing rate of efficiency with temperature becomes less when the drive current is larger.

Another interesting aspect is generation of higher harmonics by luminaires; especially LED luminaires in which LED driver is the one who controls the current injected into the LED, the total harmonic distortion in input current (THDI) [9] and the power factor (PF).

Highly distorted current has been a concern with other technologies as CFL lamps and a large number of studies were conducted over the past decade [1]. One of them [14], analyses the harmonic impacts from compact fluorescent lights on distribution systems, concluding that high penetration levels of CFLs with high distortion, electronic ballasts can result in unacceptable voltage distortion levels on distribution systems. Similarly, LED lighting is creating significantly distorted current, different LED lamps types with different power levels will have different THDI [8].

Permissible limits for harmonic current emissions in lighting equipment are specified in IEC 61000-3-2 [15]. LED sources fall in the class C category of equipment with input power less than 25 W, and LED luminaires falls in the category of class C of equipment with input power greater than 25 W. According to the input power the limits are less or more restrictive. For luminaires (> 25 W) limits are clearly specified and highly restrictive.

Many studies have shown a bad quality of LED drivers included in such lamps. These drivers cause noise and can lead to bad quality electrical energy. The paper [16] studied electrical parameters for wirelessly controlled color and dynamic white LED lamps of the Hue type which emit optical radiation in three different colors: Green, red and blue, or three CCT values. Measurements of the total harmonic distortion THD and power factor PF coefficients were performed for different RMS values of feeding voltage. It was showed that the level of distortions increases with the decrease in the RMS voltage. The THD values of the supplying current strongly depend on the color of the emitted light and feeding voltage. The highest THD value was obtained for neutral white light and is 59%, while the lowest THD value was obtained for warm white light and is equal to 46%.[16]

Another study [17] has shown that a switched power supply incorporated in the LED lamps and used to control the light diodes cause very strong distortions of the current signal and hence generates higher harmonics of the current. This study found that when the lighting system operates solely with one type of light source, the harmonic distortion of current remains constant irrespective of the change of power (pieces) of the light fixtures. Completely different characteristics of the total harmonic distortion of current intensity THDi in the function of the active power of load were obtained when LED light sources manufactured by various companies operated at the same time.[17]

Similarly, study [18] analyzes the impact of load resistance (or LED module load) on THD for two types of LED lamp power supply. THD coefficient values were determined for several different values of LED module load. It was proved that the power supply of one type of lamp generates smaller distortions, and THD does not exceed 26 % when it is loaded with an LED module. The second lamp power supply type is characterized by the THD coefficient which is three times higher.

Reference [19] shows the analysis of low-wattage LED bulbs 4 W and 7 W in cool white and warm white with and without harmonic filters in their drivers. This paper evaluates the harmonic parameters of low wattage warm white and cool white LED lamps of different ratings manufactured by the same brand. This study presented the experimental results on harmonic generation from both warm and cool white LED bulbs that are currently used in residential, commercial, and industrial lighting. The tested lamps THDi values range from 9.5 % to 127.5 %. The 4 W warm white LED has a 127.5 % harmonic distortion level and 7W cool white LED which has 119.7 % harmonic distortion. The warm white LED bulbs shown a higher contribution towards harmonic emission compared to cool white LED bulbs.

The present work detailed evaluation of current, and power behavior of 3 LED luminaires LEDEX (150 W, 180 W and 240 W) [20] and 1 sodium luminaire Schreder Ambar 3 (400 W) [21] during temperature changes, see Fig. 1. Additionally, the behavior of the third current harmonic is presented in each of the tests performed.

This type of luminaire is of special interest. The sodium is still used to illuminate certain roads and the replacement by LED luminaires is typically using luminaires with powers similar to those studied in this work. The behavior of the electrical parameters is analyzed that could influence electrical network power quality.

Fig. 1. Experimental luminaires pictures

Primary purpose is to compare the electrical behavior of both technologies and secondary is to analyze the influence of temperature on luminaire performance.

2. METHODOLOGY

The authors measured four luminaires (1 SODIUM, 3 LEDs) for public lighting in the experiment. The experiment consisted of 2 stages. First, the experiment was realized in a room without temperature control. Second, they were subjected to measurements (according to Fig. 2) in a room with a constant temperature-controlled system (±1 °C, measurements in under air conditioning conditions).

Table 1 shows the characteristics of each measured luminaire.

Table 1. Technical characteristics for tested luminaires

Name	Nominal Power [W]	Luminous Flux [lm]	Technology
LED 1 5000 K	150	19500	LED
LED 2 5000 K	180	23400	LED
LED 3 5000 K	240	31200	LED
SODIUM 2300 K	400	46069	HPS

Each luminaire is tested individually and connected to a single-phase voltage of 240 V using an AC controlled voltage source (±2 %).

The observation period is bigger than one day. This is necessary to observe changes in electrical magnitudes with the influence of temperature variations during a day. The measurement aggregation time interval is 10 minutes for parameter magnitudes: power, current, harmonic distortion and LED driver temperature, and 1 minute for environment temperature.

Electrical measurements are made with two electrical power quality analyzers (METREL MI 2892, SONEL PQM-711). Temperature measurements are made with METREL temperature probe and Testo 174H Mini temperature and humidity datalogger, all calibrated in Laboratory that has ISO/IEC 17025 certificate. The METREL temperature probe measures the driver temperature inside the luminaire. Testo data logger measures the environmental temperature. Figure 2 shows the measurement scheme.

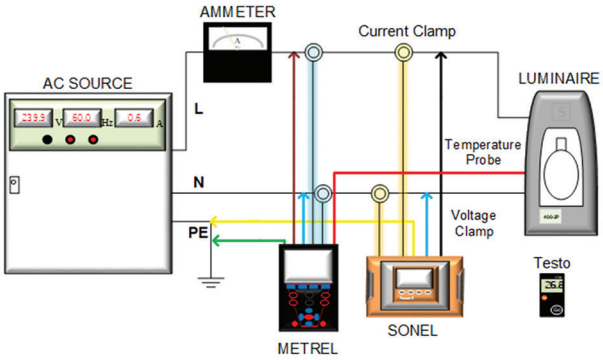

Fig. 2. Schematic diagram of experimental setup

Measurements are carried out in two scenarios, the first without air conditioning and the second in an air-conditioned room at controlled temperature of 25 °C ± 1 °C. So, each luminaire is tested two times for more than one day.

During the measurements, there were no other influences on the temperature variations. The test room is an dark room, that is, there are no windows that allow external light to enter. Additionally, during the period in which the luminaires were measured, the door was kept closed.

The measurement curve results are smoothen and normalized using a computer program. The curves were compared with the Pearson correlation coefficient between each electrical parameter and temperature.

$$r = \frac{\sum_{i=1}^{n}(T_i - \bar{T})(x_i - \bar{x})}{\sqrt{\sum_{i=1}^{n}(T_i - \bar{T})^2}\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}}$$

Where, T is temperature and x represents current, power and thirth harmonic in each calculation. The values were found in Origin 9.1 software.

It is interesting to observe the reaction of the electrical parameters such as power, the third harmonic and current as a function of the temperature variation at a constant voltage since they influence the power quality of the electrical network.

It is expected to find relationships between electrical parameters and temperature variations at a constant power supply in a thermally controlled environment as well as in uncontrolled environment.

3. RESULTS AND DISCUSSION

In this section, the measurements results are summarized in graphs. Measurements made under constant temperature conditions represent Scenario 2 and measurements without air conditioning represent Scenario 1.

3.1. ELECTRICAL POWER AND TEMPERATURE

The next figures show the results of power and temperature in each luminaire.

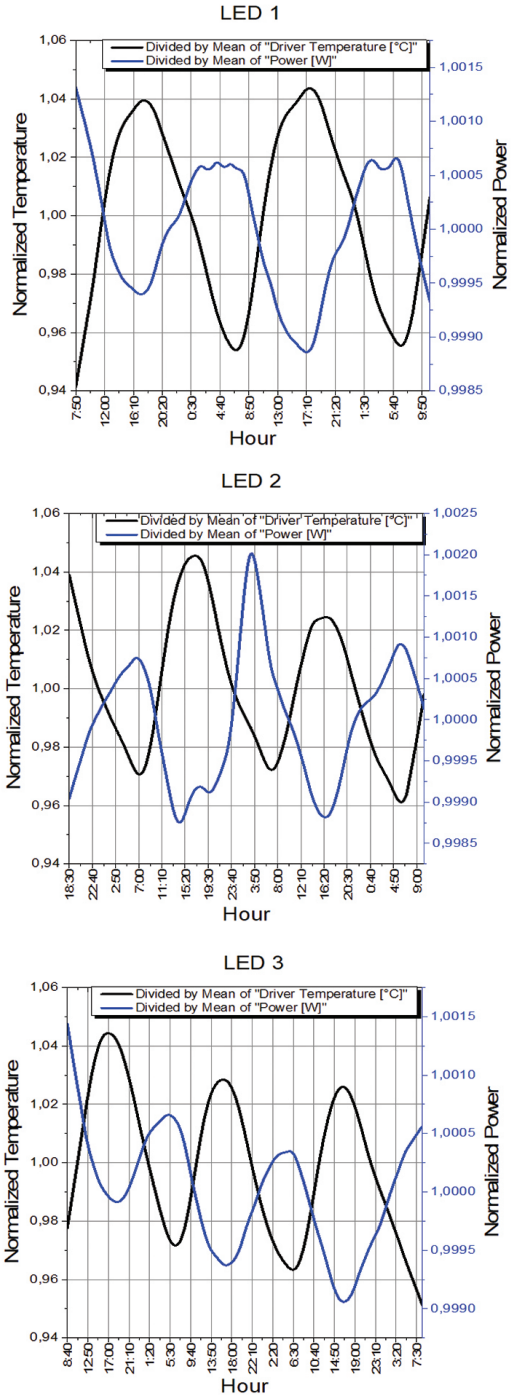

Fig. 3. Luminaire's driver temperature divided by mean (LED 1: 48.1°C; LED 2: 47.3°C; LED 3: 60.9°C) and power divided by mean (LED 1: 157.9 W; LED 2: 169.9 W; LED 3: 236.4 W)

Figure 3 represents LED driver temperature and power results at test conditions of Scenario 1. It shows that LED driver temperature behaves in the same way as environmental temperature. The behavior of current and power is identical, since the supply voltage is constant (Figure 4). The correlation between temperature and power at Scenario 1 of all tested luminaires are presented in Table 2.

Figure 4 shows the results of room temperature and current at Scenario 1, in that condition the next results are observed:

- For SODIUM luminaire, temperature variations over the course of a day in the room without air conditioning are around 4.7 °C, with this temperature variation electrical power change 2 W. The correlation coefficient r is (94±1) % and there is a strong and direct correlation between power and temperature in sodium luminaire.

- For LED 1 luminaire, a temperature variation of 5.6 °C changes electrical power around 0.5 W. There is a strong correlation between temperature and power (r= 94±1 %), but in this case, there is an inverse correlation.

- For LED 2 luminaire, a temperature variation of 4.9 °C changes electrical power around 0.8 W, again, there is an inverse correlation between temperature and power.

- For LED 3 luminaire, a temperature variation of 5.7 °C changes electrical power around 0.8 W, there is an inverse correlation between temperature and power.

Table 2. Correlation coefficients between temperature and power, Scenario 1

	Correlation Coefficient r (%)	
	Power vs. room Temperature	Power vs. Driver Temperature
LED 1	(94±1) %	(88±3) %
LED 2	(86±1) %	(85±3) %
LED 3	(54±2) %	(55±7) %
SODIUM	(94±1) %	-

Figure 5 represents the results of temperature and current at Scenario 2. Under controlled temperature test conditions, there is not significant correlation between room temperature and power, the correlation coefficient for SODIUM luminaire is (50±3) %, LED luminaires also have lower correlation coefficients. The correlation coefficients for LED 1, LED 2 and LED 3 reduce to 75 %, 16 % and 18 % respectively.

In Scenario 2 test conditions LED luminaires have greater electrical current than Scenario 1.

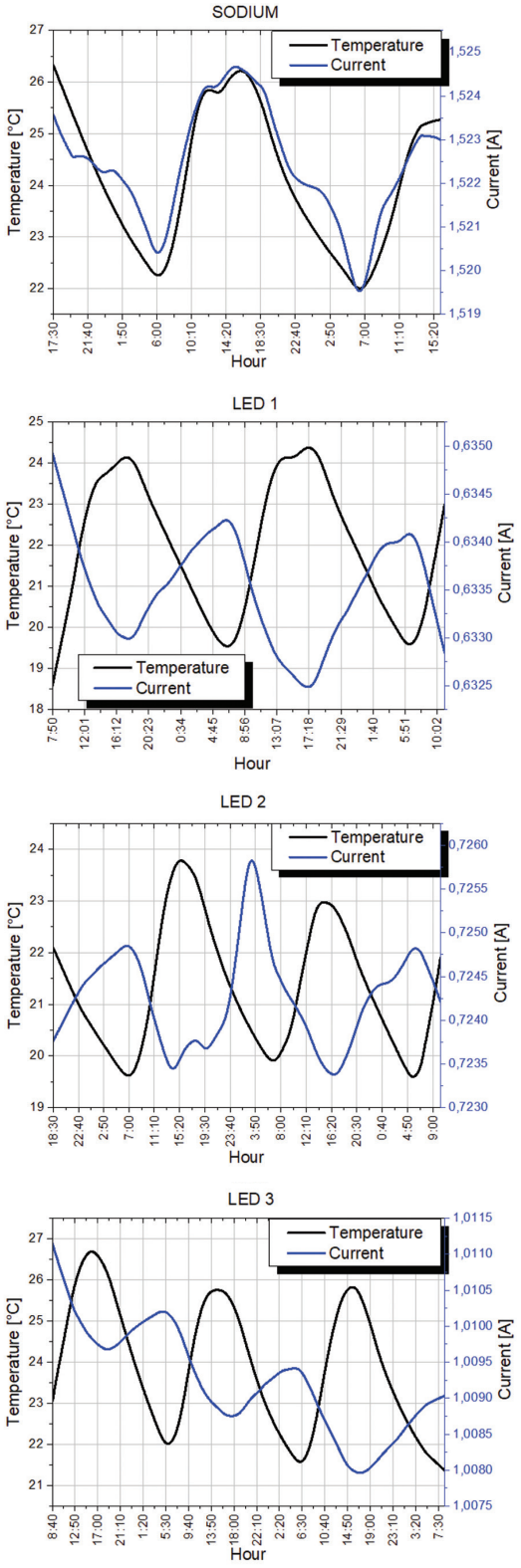

Fig. 4. Luminaires current and room temperature, Scenario 1

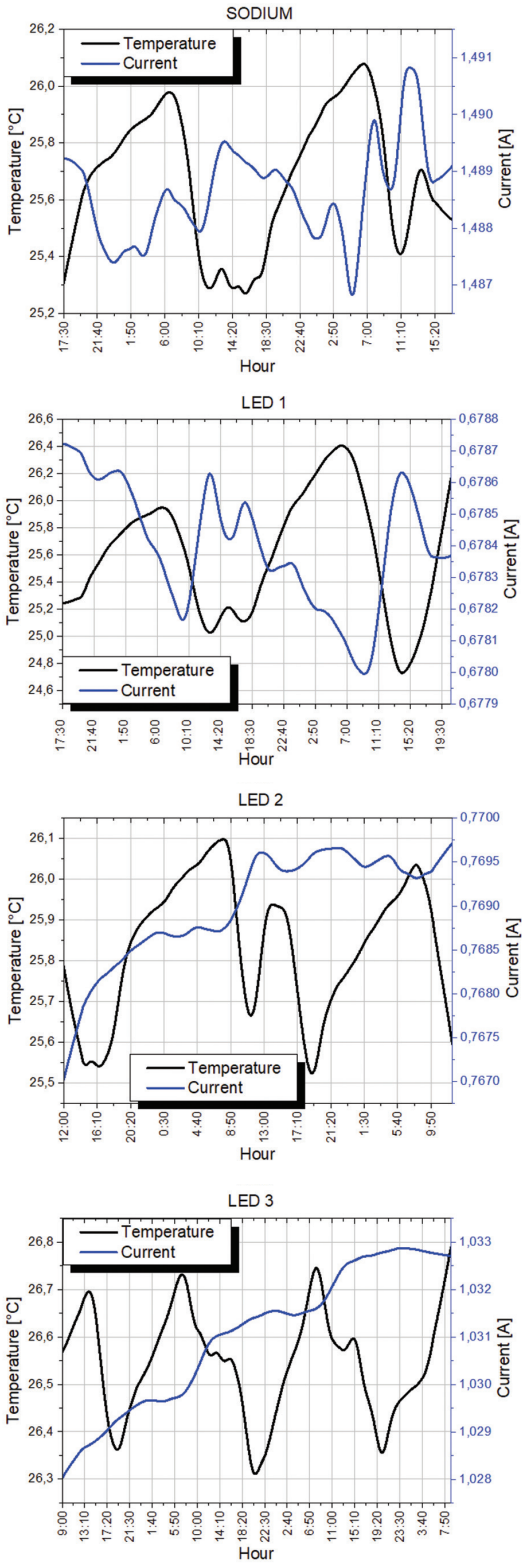

Fig. 5. Luminaires current and room temperature, Scenario 2

3.2. CURRENT AND TEMPERATURE

The current is directly related to power. The Figure 4 and Figure 5 show the results of room temperature and current at Scenario 1 and Scenario 2, respectively. Driver temperature behaves in the same way of room temperature. Their results of correlation coefficient are shown Table 3.

Figure 4 shows the results for current and temperature of luminaires at test conditions of Scenario 1, for SODIUM luminaire the behavior of current is the same as power and both correlation factors are similar (Table 2 and 3).

However, with a temperature variation of 4.7 °C current changes are not significant.

For LED luminaires correlation between current and temperature is inversely as for power, and there is strong correlation for LED luminaries of 150 W and 180 W. Despite the high correlation between temperature and current the changes in this last are not significant.

Table 3. Correlation coefficient between temperature and current of luminaires, Scenario 1

For LED 3 there is poor correlation due to a continuous current decrease on the luminaire, however peaks and valleys of temperature are reflected in current.

Figure 5 shows the results with air conditioning of room temperature and current. At controlled temperature test conditions, correlation coefficients between temperature and current are similar to correlation coefficients between temperature and power.

Table 3. Correlation coefficient between temperature and current of luminaires, Scenario 1

	Correlation Coefficient r (%)	
	Current vs. Environment Temperature	Current vs. Driver Temperature
LED 1	(93±1) %	(91±3) %
LED 2	(84±1) %	(80±4) %
LED 3	(8±19) %	(9±56) %
SODIUM	(95±1) %	-

3.3. THIRD CURRENT HARMONIC AND TEMPERATURE

Figure 6 shows that 3rd harmonic is the most significant in HPS luminaire and LED luminaires. LED luminaires, unlike HPS luminaire, present high order harmonics. For HPS luminaire, high order harmonics reach zero.

Considering that 3rd harmonic is the most significant, only 3rd harmonic is analyzed in section 3.4.

Third current harmonic and temperature results show that LED luminaires have a strong and direct correlation between third current harmonic and temperature.

Table 4. Correlation coefficient between temperature and 3rd current harmonic, Scenario 1

	Correlation Coefficient r (%)	
	Third harmonic vs. Environment Temperature	Third harmonic vs. Driver Temperature
LED 1	(95±1) %	(96±2) %
LED 2	(93±1) %	(83±3) %
LED 3	(93±1) %	(97±1) %
SODIUM	(34±5) %	-

In table 4, all LED luminaires have strong and direct correlation between temperature and third current harmonic, compared with previous results, third current harmonic is the most related to temperature.

The mean results of third current harmonic expressed as percentage of the fundamental current and their changes due to temperature are 16.2 % for SODIUM, 4.3 % for LED 1, 5.4 % for LED 2 and 6.2 % for LED 3.

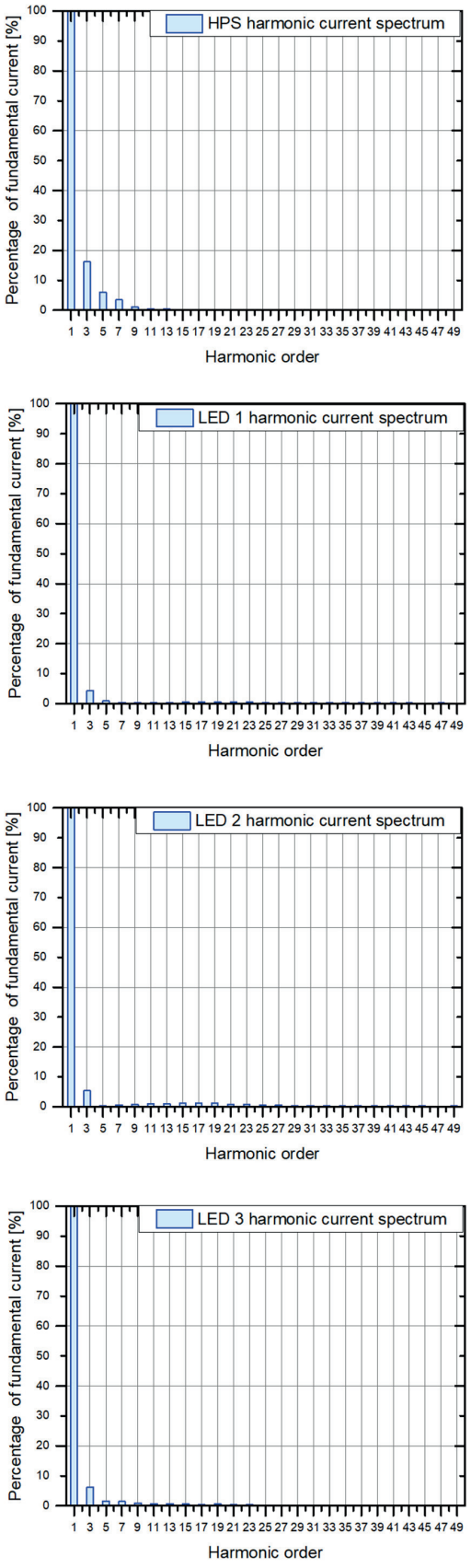

Fig. 6. Luminaires harmonic current spectrum

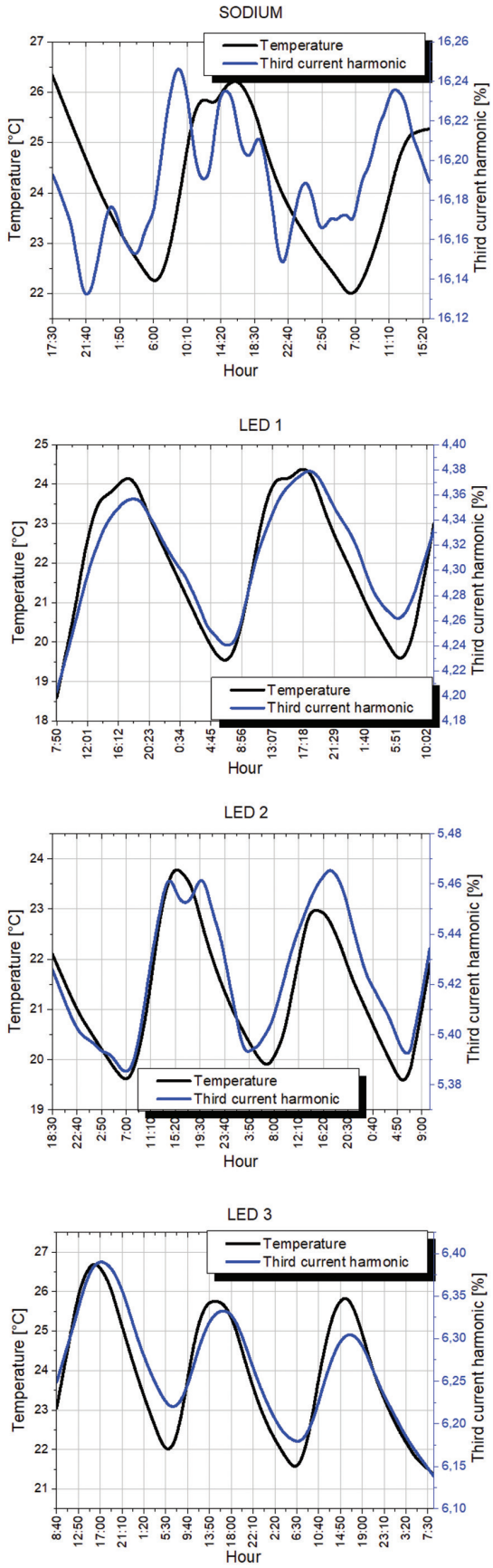

Fig. 7. Luminaires 3rd current harmonic and temperature, Scenario 1

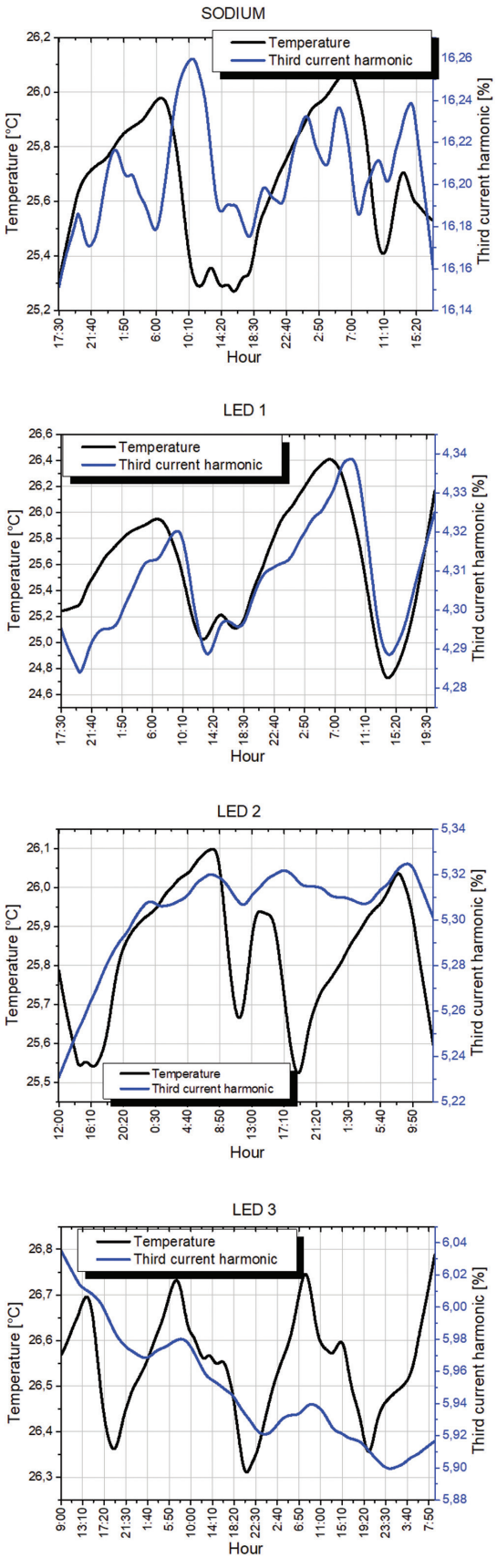

Fig. 8. Luminaires 3rd current harmonic and temperature, Scenario 2

SODIUM luminaire generates higher current harmonic distortion than LED luminaires, however all luminaires meet the limits of the standard IEC 61000-3-2. These average results do not change significantly at Scenario 2.

In Figure 7, LED 1, LED 2 and LED 3 third current harmonic expressed as percentage changes 0.1 %, 0.11 % and 0.2 %, with a temperature variation of 5.6 °C, 4.9 °C and 5.7 °C respectively, for SODIUM luminaire there is not strong correlation between third current harmonic and temperature, however a temperature variation of 4.7 °C changes 0.31 % of third current harmonic.

Figure 8 represents room temperature and third harmonic results of luminaires at test conditions of Scenario 2. At controlled temperature test conditions the correlation factor is reduced. LED 1 correlation coefficient reduces to (79±1) % and third current harmonic changes are also less (<0.1%), correlation coefficients of the other luminaires are similar to correlation coefficients between temperature and power.

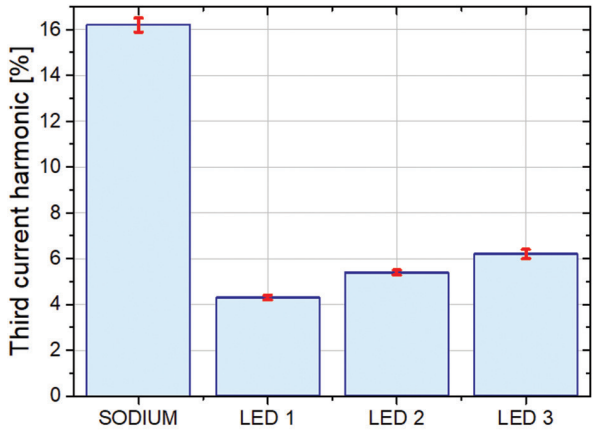

Fig. 9. Luminaires third current harmonic expressed as percentage of the fundamental current

Total results at Scenario 1 are summarized in the next figures and show:

- The dependence of current and power variations, which are always on the same direction.
- SODIUM luminaire power, current and third current harmonic measurements are directly related to temperature. High temperatures facilitated electrical discharge inside SODIUM lamps, but thanks to the ballast current flow remains almost constant (Figure 10).
- LED luminaires power and current are inversely related to temperature (Figure 11, 12, 13), an increasing temperature decrease luminaire's current. As indicated in [9], higher LED die junction temperatures, resulting from changes in ambient temperature reduces the current flow, however LED's drivers maintain current and power almost constant, LED's drivers are also responsible of the low third current harmonic on LED luminaires.
- Although the percentage of current harmonics increases as LED luminaire power increases, this is still much lower than the obtained for SODIUM luminaire.

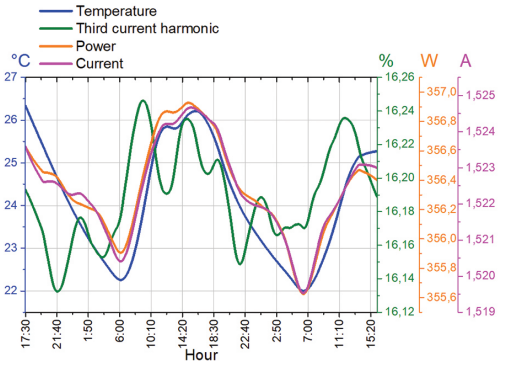

Fig. 10. SODIUM luminaire current, power, third current harmonic and temperature

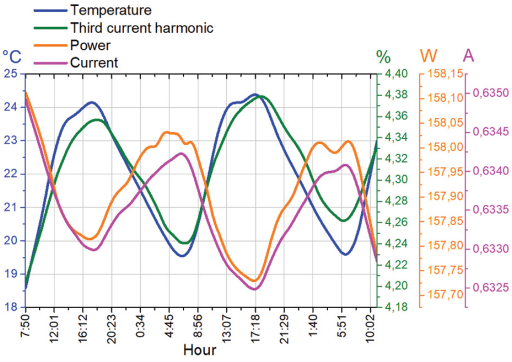

Fig. 11. LED 1 luminaire current, power, third current harmonic and temperature

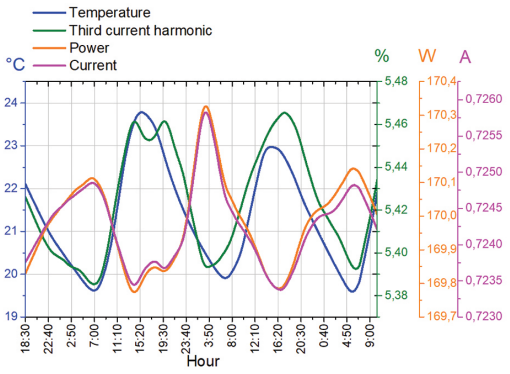

Fig. 12. LED 2 luminaire current, power, third current harmonic and temperature

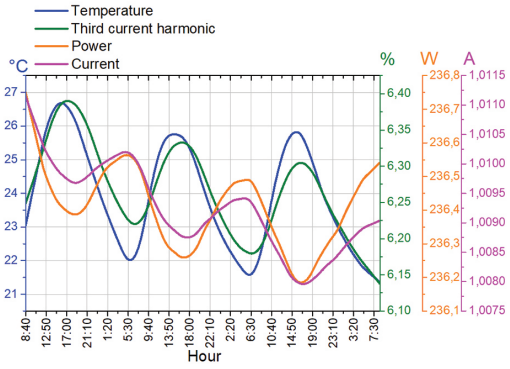

Fig. 13. LED 3 luminaire current, power, third current harmonic and temperature

4. CONCLUSION

LED luminaires are sensitive to temperature in both Scenarios. Third current harmonic is directly related to temperature while power and current are inversely related. Power of LED luminaires changes around 0.1 W/°C, however, the changes in current magnitudes are not significant, this shows the good performance of LED drivers.

LED 3 correlation coefficients are lower compared with correlation coefficients of LED 1 and LED 2 luminaires due to a continuous current decrease which affects the calculation of correlation coefficients, however the results obtained for third current harmonic agrees with the results of the other LED luminaires.

SODIUM luminaire is sensitive to significant temperature changes. Current, power and third current harmonic are directly related to temperature, current and power have strong correlation coefficients with temperature, however, third current harmonic has a poor one. Power of SODIUM luminaire changes around 0.4 W/°C. At controlled temperature test conditions coefficients between temperature and electrical magnitudes are not significant for SODIUM luminaire.

LED luminaires generate lower current distortion than SODIUM luminaire. LED's drivers of the luminaires tested generate fairly low harmonic distortion values and high-power factor.

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