

# Performance Evaluation of Energy Harvesting for the IoT Based on Fuzzy Logics

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**Abstract**— Numerous energy harvesting wireless devices that will serve as building blocks for the Internet of Things (IoT) are currently under development. Basically energy efficiency stands as vital requirement that makes wireless protocols and technologies ideal for use in IOTs. Thus nodes in IOTs are battery-powered, so a low-power feature is a fundamental requirement. This paper represents that many energy efficient techniques have been proposed so far for better energy consumption. Out of them fuzzy based IOTs has shown quite effective results but still it can be improved further by introducing other membership functions. The main motive of this paper is to propose gaussian functional shapes based membership function for optimizing and reducing energy consumption in IOTs.

**Keywords**— Internet of Things (IOT), Wireless Energy Harvesting Units, Fuzzy Logic and Gaussian Membership Functions

## I. INTRODUCTION

Internet of Things is wise infrastructure of particular devices able to wirelessly connecting together, services as well as individuals on a huge level, over the Internet [1]. Its motive is to making the Internet as well as invasive and having the possibility to impact the total well being for gamers in numerous aspects. The networked varied devices linked in an IOT arrangement are developed with sensors, controlling processors together with a source of energy to check the atmosphere as well as send/receive information. Applications envisioned for IOT period many fields like house computerization, healthcare, observation, intelligent surroundings as well as lots of more. Among the list of leading barriers in implementing this sort of high-flying method is providing sufficient energy to function the network in the autonomous mode not including compromising quality of service. Although you will find a great number of techniques to attain energy effectiveness, for example utilizing lightweight communication protocols [2] as well as adopting low-power radio transceivers [3], the present innovations leaning in energy harvesting supplies significant approach to extend battery durability. Therefore, energy harvesting just means for the rising IOT [4].

### 1.1 Wireless Energy harvesting Unit

The WEH get the transmitted radio waves utilizing an antenna as well transfers the conventional RF energy into a mild direct current (DC) source of energy to offer the sensor device. Usually, poor IOT, wireless sensor networks as well as radio-frequency identification (RFID) tags; wireless powers are frequently divided into various classes [6]:

1) *Dedicated source*: These sources are deployed start using a conventional energy provide about the device. This is often optimized regarding frequency as well as highest capacity that is eligible the sensor devices. Mobile node is a particular DS.

2) *Ambient source*: These kinds of source are further placed in two types:

a) Static or anticipated ambient sources, that have been transmitters which radiate stable control of their time, aren't optimized (such as, regarding frequency as well as transmitted power) toward offer the sensor device. Sink base station, broadcast radio as well as TV are degrees of predictable ambient sources.

b) Dynamic or unknown ambient sources that have been transmitters which broadcast periodically in such a way not restricted over the IOT scheme. Harvesting energy for example sources need WEH to keep an eye on the channel for harvesting opportunities. Wi-Fi access points, microwave radio links are degrees of unknown ambient sources.

## II. PROPOSED ALGORITHM

### 2.1 Fuzzy Logic:

Fuzzy approach will depend on easy rules, that are super simple to use as well as obtain fewer time. Use of this tactic will work for pixel level image fusion. This plan forms an alternative solution replacement for many conventional approaches that is with some other host of empirical relations. Empirical approaches are time intensive and make up a low correlation. Fuzzy Logic method may also become sensor fusion. This sensor fusion could are persons in a variety of sensor fusion if you do the functions may be input as well as decision may be output. The laptop can often be skilled to the input information on the sensors. The essence is usually to

correlate the given sensory inputs with various choice outputs. After developing computer another input data works to learn the performance together with the system.

### 2.1.1 Fuzzy membership function

Fuzzy categorization is the mainly applying fuzzy logic which utilized to take care of classification problems. In continuing enlargement of a fuzzy classification scheme, the top should be to make membership functions as well as to get many appropriate fuzzy rules inside the fuzzy classification scheme [5]. Fuzzy membership functions as well as fuzzy rules could be formulated specialized in specialist information method alongside alternatively utilize information driven method. This type of methods correspond with the concept to manual or automatically by means of machine learning process specialized in training instances correspondingly, generally specialist information is utilized to formulate membership function array in the event after that rules for implication as well as improvement simply because it connect to domain information nonetheless it might be subjective with various experts generating various membership functions as well as policy for same purpose. Additional method of generation of fuzzy membership functions on such basis while the input information will transfer information into linguistic terms [5].

Fuzzy logic idea can be compared to the human beings being's feeling and inference process. Unlike classical control strategy, which is a real point-to-point control, fuzzy logic control can be a range-to-point or range-to-range control [6]. The production of a fuzzy controller emanates from fuzzifications of both inputs as well as outputs when utilizing the linked membership functions. A input may be become different the linked membership functions predicated on its value. By using perspective, the production of a fuzzy logic controller is founded on its memberships of various membership functions, that is regarded as a range of inputs.

To execute fuzzy logic process to a true application necessitates as follow:

1. *Fuzzifications* – exchange typical information into fuzzy information or Membership Functions (MFs) [5].
2. *Fuzzy Inference Process* – unite membership functions using the control rules to take the fuzzy output [6].
3. *Defuzzification* – utilizing various strategies to compute each linked output as well as place them in with a table. Grab the output through the table on such basis as the latest input through a questionnaire [5].

#### a) Gaussian Membership Function:

Gaussian fuzzy membership functions are well liked inside the fuzzy logic, because they are the cause the outcomes of

fuzzy systems and radial basis function (RBF) neural networks. Fuzzy membership function that can often be accustomed to represent vague, linguistic terms could be the Gaussian and that is written by:

$$\mu_{A_i}(x) = \exp\left(-\frac{(x - c_i)^2}{2\sigma_i^2}\right) \quad (1)$$

where  $c_i$  and  $\sigma_i$  are the centre as well as width of the  $i$ th fuzzy set  $A_i$ , respectively.

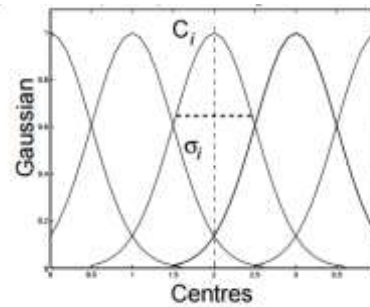


Fig 1: Representing Gaussian functions

### III. RELATED WORK

Collata et al. (2015) [2] proposed the energy proficient is the principle necessity generates wireless protocol to utilized in IOT. BLE has a potential in turning into a critical technological improvement with the IOT within small electrical power, little attempt, along with tiny devices. Mario.collotta (2014) [3] proposed architecture, comes with a strategy to power the sensor nodes based upon piezoelectric materials which let it produce potential energy making the most of the vibration produced with the passage of vehicles about the road. Toklu et al. (2014) [4] presented the energy consumption is the major issue as the devices, processors and memory forming sensor networks are small and usually battery powered. Eleonora Borgia et al. (2014) [5] discussed that the Internet of Things (IoT) is a new paradigm that merges aspects and technologies coming from different approaches. F. Zarafshan (2012) [6] work with a fuzzy logic controller to relieve the communication overheads during flooding and routing your data stream through the source(s) to some sink node. The fuzzy logic controller evaluates the potentiality of intermediate nodes to coordinate in mission, dependant on each node's traffic load, energy residual and size of information that is maintained. Rani et al. (2012) [7] considered in the paper incorporate boosting network scope, availability, system lifetime and minimizing movement load. Ajofoyinbo et al. (2011) [9] proposed the use of Fuzzy set theory have been upgraded for taking care of overlapping domains in control designing yet this has for the most part been inside of the setting of triangular membership functions. Hameed and Ibrahim A (2011) [10] proposed technique is displayed as a three fuzzy node framework. Haining Shu et al. (2008) [13] proposed approach depends on fuzzy logic systems to evaluate the time of wsn recognized

the model just one node existence in WSN, Gaussian MF with unsure standard deviation is mainly suitable.

#### IV. GAPS IN LITERATURE

Kamalinejad, Pouya, et al. [1] presented a summary of technologies for proficient WEH, focus the time of WEH-enabled IOT strategy, as well as briefly review the long term trends. By conducting the review, it can be obtained that the earlier study has neglected many issues that might enhance the performance of IOTs further.

1. The existing literature has not considered Gaussian functional shapes as membership functions of fuzzy logic that could enhance the accuracy as well as strength of IOTs.
2. The existing work has not considered the outcome of overheads that might be degrading the computational performance of IOTs.
3. Effects of the node harvesting is also ignored in the majority of existing fuzzy based energy efficient IOTs.

#### V. ANALYSIS OF RESULTS

The proposed technique is designed and implemented in MATLAB tool u2013a. Here we will compare the performance of existing and proposed Fuzzy based IOTs by considering energy harvesting based sensor nodes. The graphical comparison has been carried out between proposed technique i.e. gaussian functional shapes as membership functions of fuzzy logic with existing technique is triangular functions of fuzzy logic on the basis of parameters like energy consumed, execution time and overheads.

##### 5.1 Energy Consumed

Energy consumption is the amount of energy or power used.

$$E = PT$$

Table no.1: Comparison of Energy Consumed

Iterations	Existing Results	Proposed Results
1	1.2906	0.5119
2	1.2287	0.5742
3	1.0132	0.5525
4	1.1323	0.483
5	1.3626	0.5469
6	1.089	0.5415
7	1.4058	0.509
8	1.5646	0.523
9	1.1782	0.5254
10	1.4817	0.5196
11	1.1995	0.6167

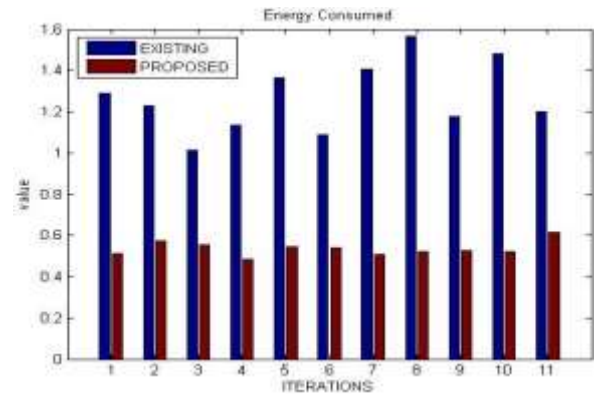


Fig 2: Performance Analysis of Energy Consumed

It represents that the proposed Consumed Energy is comparatively lower than existing one.

##### 5.2 Execution Time

The difference between the finish time of job and the start time of the job is called execution time.

The formula which is used for execution time is shown in equation 2:

$$E_x = F_t - I_t \quad (2)$$

Where  $F_t$  finish is time and  $I_t$  is Initial time

Table no.2: Comparison of Execution Time

Iterations	Existing Results	Proposed Results
1	3.912	3.0455
2	2.7389	2.2939
3	1.9551	1.4261
4	1.5625	1.1531
5	1.1407	0.6678
6	1.018	0.6623
7	1.018	0.3736
8	1.028	0.2345
9	0.992	0.0883
10	1.034	0.006
11	1.046	0.0552

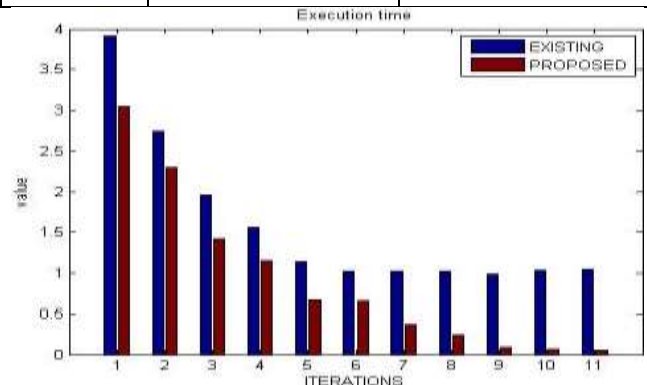


Fig 3: Performance Analysis of Execution Time

The graphical representation of fig 3 has shown that execution time using proposed algorithm decreases than existing technique.

### 5.3 Overheads

Overhead is usually stated each and every combination of extra or indirect computation period, storage, data transfer rate or other assets that will be needed to acquire a particular objective.

Control Overhead

$$= \text{Total Execution time} \\ - \text{Computation time}$$

Table no.3: Comparison of overheads

Iterations	Existing Results	Proposed Results
1	9.2257	3.2276
2	8.4695	4.2647
3	7.274	3.4243
4	7.9849	3.1642
5	9.7026	4.2016
6	7.6575	3.7426
7	9.9121	3.8143
8	11.0652	3.7235
9	8.1771	3.7804
10	10.2	3.8706
11	8.1996	4.736

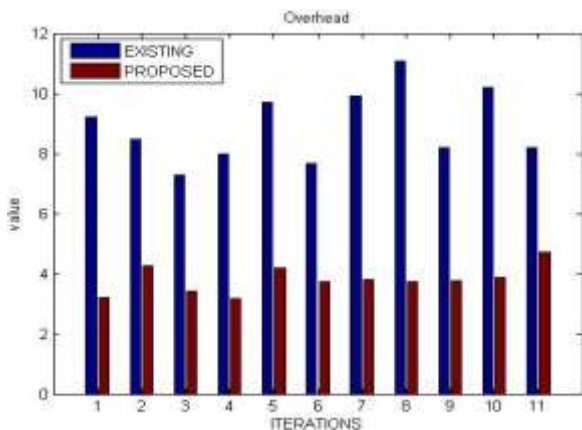


Fig 4: Performance Analysis of Overheads

It clearly shows that our proposed overheads are comparatively lower than the existing one.

## VI. CONCLUSION

The various technologies and schemes has been enabled wireless energy harvesting for IOT systems. The main objective of this paper is too focused on fuzzy based harvesting and heterogeneous nodes in IOTs networks for improving the energy utilization. In this paper it represents that in existing literature has not considered the use of

Gaussian functional shapes as membership functions in fuzzy logic IOTs. So to improve this new method has been proposed i.e. by utilizing Gaussian functional shapes as membership functions in fuzzy logic. The comparison has been drawn between existing and proposed technique by using various parameters like energy consumed, execution time and overheads. The proposed technique is designed and implemented in the MATLAB 2013a by using wireless processing toolbox. Hence there is Gaussian MF's shapes have tendency to increase accuracy and precision of the IOTs as well as results in reducing energy consumption.

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