A REPORT ON

A novel multi-objective optimization strategy for enhancing quality of service in IoT-enabled WSN applications

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Course Name: Mobile Telecommunication Network
Course Code: ECE F431_EEE F431
Duration: 3.5 Months **Date of start:** 14th September 2020
Date of Submission: 28th November 2020
Title of the Project: A novel multi-objective optimization strategy for enhancing quality of service in IoT-enabled WSN applications

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November, 2020

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Abstract

In today's world, due to the growth of smart grid, smart city and smart home apps, the Internet of Things (IoT) has become more important. For IoT-based applications, network longevity is regarded as an essential characteristic. The Wireless Sensor Network (WSN) provides the longevity of such networks where WSN operates in the IoT model as subnets. However in the IoT-based WSN (IWSN) model, multiple objectives such as coverage, accessibility and energy consumption are required to enhance service quality. The better development of IWSN is encouraged by the right optimization strategy of these multi-objectives. The Adaptive Coverage and Communication (ACC) framework is proposed to achieve the efficient IWSN model in this paper. It uses two fundamental methodologies in which the first method provides all target items with maximum coverage and its mathematical model ensures the coverage rate. The second approach deals with the network's access and energy use. The experimental results show that the proposed ACC scheme can support the network for a prolonged period, unlike current schemes.

Objective:

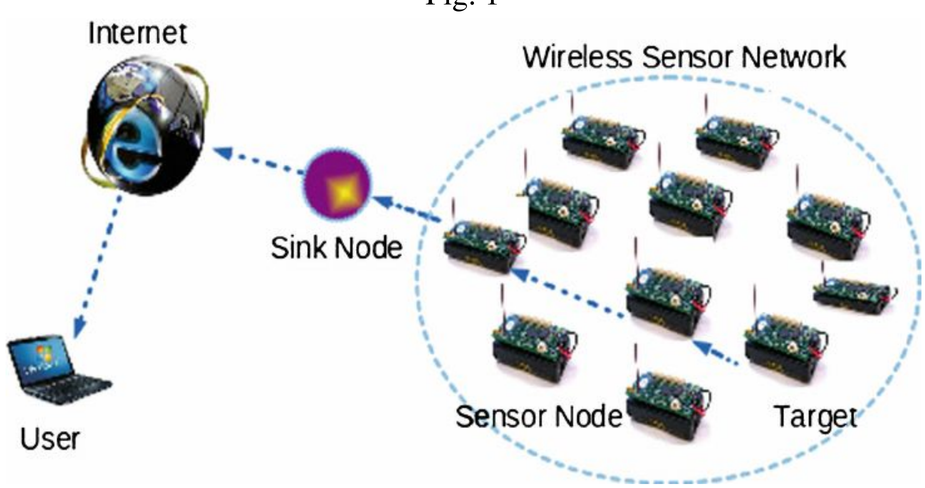
1. **Optimal Coverage :** Attaining the required sensing coverage.
2. **Optimal Connectivity :** Focusing the network connectivity among multiple nodes.
3. **Energy Conservation** : Aimed to reduce the energy consumption of the network.

Introduction

The application of IoT has changed our world greatly. It has interconnected the objects, buildings and vehicles around us to develop new value adding services and real time applications.IoT allowed us to integrate several enabling technologies with different abilities like sensing, computing, monitoring, managing, storage and connectivity. The interconnection and communication is considered as the biggest optimisation concerning the efficient development of IoT.

IoT requires eminently complex infrastructure for sensing the present information around, gathering the sensed data and to transmit them to the main sink for further application. Many technologies are being utilized for this purpose considering that WSNs(Wireless Sensor Network) will be an applicable technology for procurement of the information from the physical environment. The sensory nodes and sink are two integral parts of WSN. The major role of the sensory node is to sense the current environment, whereas the sink node handles the duty of acquiring relevant data from multiple sensory nodes. This data is made available for remote access through the internet and hence it expands the objectives of the IoT model.

Fig. 1



Smart cities, grids, mines, fire detection systems, smart homes are some current potential uses of IWSN (IoT based WSN). IWSN can systematize the operation of these potential implementations more aptly. For instance, a coal mine fire is a fatal event that often causes potential hazards to the environment and leads to lives lost in the fire. IWSN can be engaged to achieve real-time environmental observation of the aforesaid mine fire threat factors. In IWSN, every deployed sensor measures the temperature value periodically. Initially, the sensed information from the active area is compared with a definite threshold value. If the observed data exceeds the threshold value, then an alert message is forwarded to other nodes and then towards the sink through multi-hop communication. While the sink gets multiple alert messages from the various directions, it recognizes that there is a possibility of the mine fire. Finally, it reports the fire information along with the location of the originating node to the supervisor via the internet for appropriate action which is shown in Fig. 1.

Problem Statement

To improve the quality of service in the field of IoT based Wireless Sensing Network (IWSN) there is a need to improve the multi-objectives like coverage, connectivity and energy consumption of the IWSN model.

Sensing coverage of a WSN tells how efficiently the nodes supervise the area of interest. Coverage in the measurement of the network sensing ability. Connectivity of the network plays a very crucial role in the performance measure of how well the sensors can communicate. There is always a constraint over the amount of energy that can be delivered due to the rechargeable battery constraints to the WSN. Therefore, these three objectives need to be taken care of as they characterize the overall performance of the IWSN model. In this paper, we use a combination of LEACH as well as E-LEACH to attain an effective IWSN model This scheme is very efficient for prolonging coverage, maintaining network connectivity and optimal energy consumption.

Network Model

In this work, every sensor node is an autonomous wireless node having a single non-rechargeable battery system. It can change the state of operation as per requirement automatically between active and idle. Active node collects the sensed data and comes into the covered area. And it saves energy when it is idle. Every node has a time-dependent energy level.

The following hypothesis is assumed in this network model:

- All the sensor nodes remain stationary in the sensing field.
- Sensor nodes are deployed randomly to supervise the environment regularly.
- Only one sink node is located in the sensing field.
- Initially, the energy level of all sensor nodes is equal.
- There is no restriction for a sink node with respect to energy, processing power and memory.

- The sink node periodically monitors the energy level of all sensor nodes in the network.
- Nodes within the range of communication are capable of exchanging the current status about their state, energy and location.[1]

Model Parameters:

VARIABLE	VARIABLE NAME	VARIABLE VALUES
E_0	Initial Energy	0.1
ETX	Energy of transmission	50*0.000000001
ERX	Energy of Receiver	50*0.000000001
Efs	Energy Used for Reception	10*0.0000000001
Emp	Energy Consumption for Multipath Fading.	0.0013*0.000000001
p	Optimal Election Probability of a node to become cluster head	0.1
rmax	maximum number of rounds	5000
EDA	Data Aggregation Energy	5*0.000000001
d_0	threshold transmission distance	sqrt(Efs/Emp)
DpacketLen	Data packet size	4000
HpacketLen	Hello packet size	100
NumPacket	Number of packets sended in the steady-state phase	10
RR	Radio Range	0.5*Area*sqrt(2)

Mathematical Model of AC method

The sensing area of a particular node n_i is

$$SA(n_i) = \sqrt{(x_i - x)^2 + (y_i - y)^2} \leq S_R \qquad (a)$$

where $(x, y) \in \Upsilon$. The neighbor set of sensor node n_i is

$$NSA(n_i) = \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2} \leq S_R \qquad (b)$$

where $n_i \in V$ and $n_i \neq n_j$.

LEACH Algorithm

LEACH (Low Energy Adaptive Clustering Hierarchy) is first proposed by Wendi B. Heinzelman of MIT [5]. This protocol provides a conception of round. LEACH protocol runs with many rounds. Each round contains two phases: cluster setup phase and steady phase. If the number is less than the threshold $T(n)$ [6], the node becomes a cluster head for the current round. The threshold is set as:

$$T(n) = \left\{ \frac{p}{1-p(r*mod\frac{1}{p}))} \;\; if\ n \in G;\ 0 \quad elsewhere \right\} \qquad (1)$$

Where p is the probability of the node being selected as a cluster-head node, r is the number of rounds passed, and G is the set of nodes that have not been cluster-heads in the last *1/p* rounds, *mod* denotes modulo operator. Nodes that are cluster heads in round *r* shall not be selected in the next *1/p* rounds.

E-LEACH Algorithm

The E-LEACH adopts the same round concept with the original LEACH. In hierarchical routing protocols, the number of cluster-heads is a key factor that affects the performance of routing protocols. In the E-LEACH we use the minimum spanning tree between cluster heads, choose the cluster head which has largest residual energy as the root node.

Selection of cluster head

$$T_{new}(n) = \left\{ \frac{p_{head}}{1 - p_{head}(r * mod(\frac{1}{p_{head}}))} * \frac{E_{current}}{E_{initial}} \quad if\ n \in G\ 0 \qquad else \right\} \quad (2)$$

Where the $E_{current}$ is the residual energy of nodes at the *r* round, $E_{initial}$ is the initial energy of nodes. By using $T_{new}(n)$, the possibility for low residual energy nodes being cluster head is greatly reduced and the possibility for high residual energy nodes being cluster head is increased.

$$p_{head} = \sqrt{\frac{N}{2\pi}} \sqrt{\frac{E_{fs}}{E_{mp}}} \frac{M}{d^2_{toBS}\ X\ N} \quad (3)$$

In the E-LEACH, the value of p_{head} is dynamically calculated according to the formula (3).Then, sensor node is randomly assigned a number between 0 and 1, if value of the number is less than $T_{new}(n)$, the sensor node is selected as the cluster-head at the current round.

In the E-LEACH protocol, the round time $T_{current}$ is defined at the beginning of the round $R_{current}$. It depends on the optimal cluster size. Then we can define the current round time $T_{current}$ as follows:

$$T_{current} = NF_{avg}(M_{min} * \sigma + \lambda) \tag{4}$$

Where, NF_{avg} is the average number of frames for a cluster with size $1/p_{head}$. $M_{min} * \sigma + \lambda$ is the frame time of a cluster which has the minimum size (the minimum number of nodes M_{min}). After defining the round time $T_{current}$ for the current round, the base station sends the cluster information and the modified $T_{current}$ to all nodes in the network.

<u>Steady-state Phase</u>

In the steady-state phase, each node sends the collected information during its own TDMA time slot. The cluster head sends the final data to the sink by the minimum spanning tree. After receiving information of all the cluster-heads, the base station analyzes the datum and transfers those to the top man machine communication interface. According to ID and information intensity of node sending, the cluster-heads broadcast the information to the network, and prepare for the next round.

Simulation

We used 50 active nodes to simulate the WSN network. We use a combination of LEACH as well as E-LEACH to form a Combination LEACH which uses the strategy of changing the mode of algorithm with the consideration of the number of active nodes.
We have used a combination of LEACH and E-LEACH in this project.

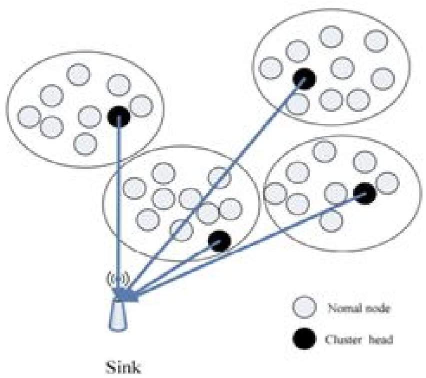


Figure 1. *Architecture of LEACH*

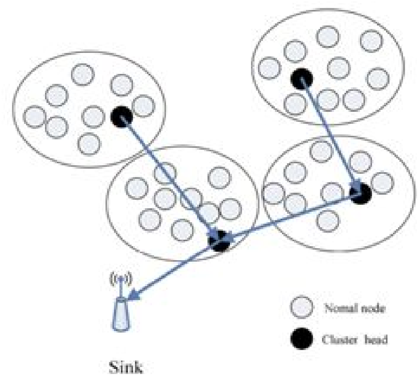
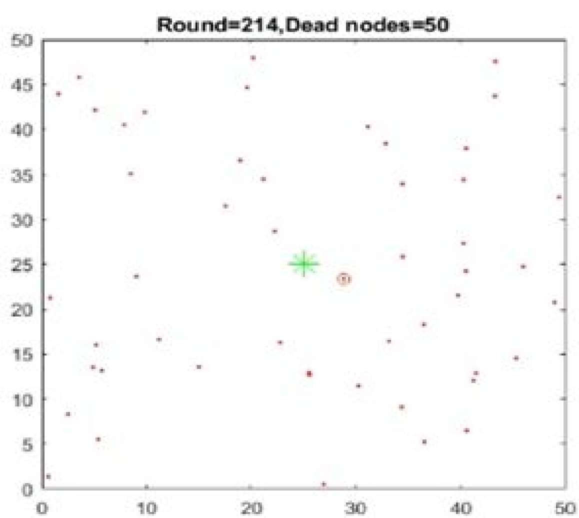
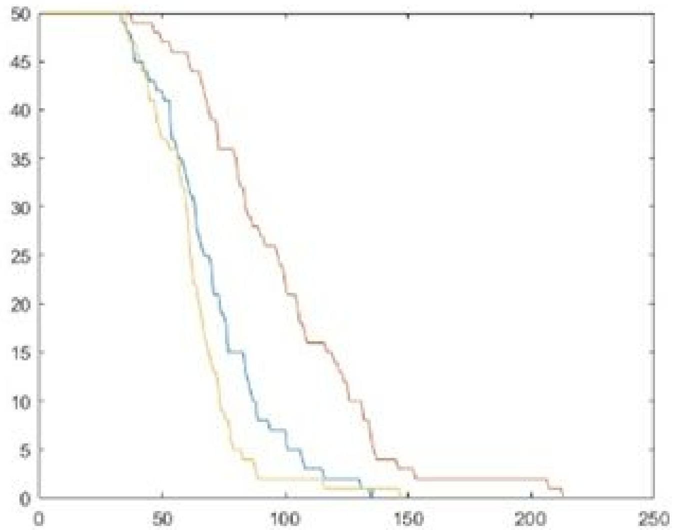


Figure 2. *Architecture of E-LEACH*

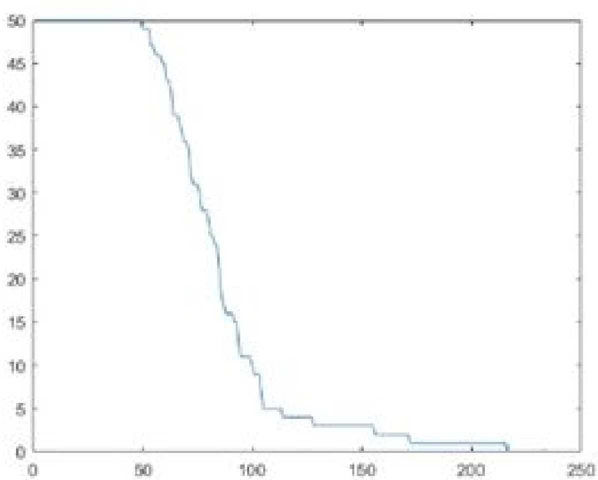
Initially we use the LEACH algorithm and then we shift to E-LEACH and we find that it gives us better results by about 20% than both LEACH and E-LEACH individually.

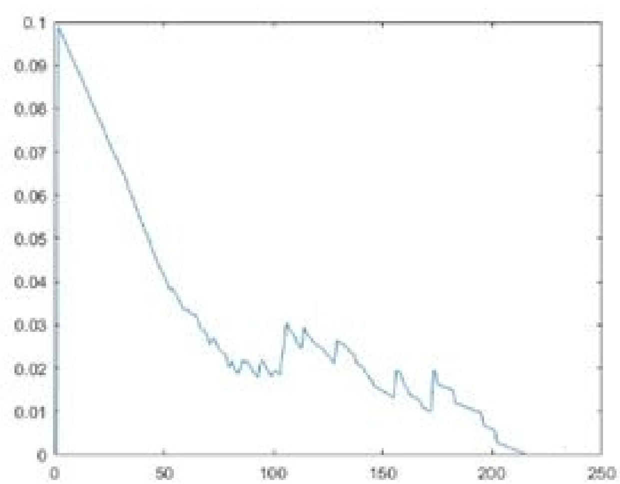


We use the following simulation pattern for the calculation of results with various forms of LEACH algorithm.
These are the graphs that compare the various methods and the results are better than the rest of the graphs.



This is the image of average energy in active nodes as shown in figure.





The main change in algorithm is selection in cluster head.

Code for the algorithm:

```
for i=1:1:n
distance to base station=Sensors distance to sink;
        Sensors new probability=
sqrt(n/(2*pi))*(sqrt(Efs/Emp)*100/(50*(dtobs^2)));
        If Sensor Energy is greater than 0
        if (Sensors(i).G<=0)
          if dead node>10 then use E-LEACH
          else use LEACH for dead nodes <1
```

Here 10 is chosen because it provides the best results in the scenario, with the help for further research there is a scope to automate the dead node number for shifting the algorithm as well as using multiple algorithms in a single code to make it more efficient.

Conclusion

Benefits of the Approach

In IWSNs, there is a sink node which gathers sensing information from all the sensor nodes in a particular area. Where Energy, Connectivity and are the three most significant objectives for guaranteeing the data forwarding from each node to a sink. In this work, the E-LEACH scheme has been proposed that tries to consider three objectives simultaneously for problem formulation. The primary step of the proposed scheme aims to build adaptive clustering hierarchy among the sensor nodes. Thereafter, it maintains the network connectivity as long as possible, while covering a sensing area as large as possible.

The experiment results are simulated in the MATLAB environment. Simulations are executed in WSN environments and a comparison with the related works is accomplished. The performance results have shown that the proposed scheme outperforms all existing schemes like Data Structures, Zone Formation and Genetic Algorithm scheme for smaller as well as larger networks. Coverage rate results validated that the proposed scheme maintains the sensing coverage as long as possible, whereas average energy consumption consumes lesser energy for coverage and connectivity process. Therefore, it can conclude that the proposed E-LEACH scheme improves the quality of service of the IWSN model through appropriate coverage, connectivity, and energy management methods.

Future Scope and required work

The Proposed Scheme has a wide range of IWSN applications in various sectors such as monitoring a fire imminent region, identifying and reporting gas leakages, tracking humidity of a certain area, tracking of animals etc. However, this project only deals with connectivity, coverage and efficiency of energy consumption of IWSNs, to make practical use of IWSN possible in the future, we need to look at other factors such as secure transmission of data between nodes. Furthermore, these schemes are proposed in a homogenous environment with all the WSNs having the same specifications and a simple area to cover. To have a better understanding of practical use of IWSNs, tests in heterogeneous environments with distinct parameters for WSNs need to take place.

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Glossary

IoT	The Internet of things (IoT) describes the network of physical objects—"things"—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the Internet.
WSN	Wireless sensor network (WSN) refers to a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at a central location.
TDMA	Time-division Multiple Access) is a channel access method for shared-medium networks. It allows several users to share the same frequency channel by dividing the signal into different time slots. The users transmit in rapid succession, one after the other, each using its own time slot.
IWSN	IoT based Wireless Sensor Networks
LEACH	Low-energy adaptive clustering hierarchy (LEACH) is a hierarchical routing protocol used in wireless sensor networks to expand the network lifetime. In the LEACH protocol, sensors arrange themselves in a cluster, and a single node of these nodes performs a cluster head.
E-LEACH	End to end secure Low-energy adaptive clustering hierarchy.