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Abstract— **currently the world is adopting Internet of Things (IoT) as the future technology and the interest IoT development is increasing. As it's expected to be the leading technology by 2022 according to Gartner. WSN is the main technology component of the IoT since it rely on sensing and collecting data in a specific filed of interest. As the WSN main issue is the network life time due the limitation in sensors resource. Therefore, such lifetime-constrained devices require enchantment on the existing routing protocols to prolong network life time as long as possible. In our paper we propose enhancement in the well know WSN routing protocol LEACH by proposing a new Energy aware algorithm in communication within cluster, hence reduce power consumption in communication process .**

***Index Terms*—WSN, Routing protocol, Power Aware, LEACH, SPIN.**

i. INTRODUCTION

Internet of Things (IoT) is a network of physical Objects, vehicles, buildings and other elements - Integrated with electronic devices, software, sensors, and network connection allows these objects to collect and share data. Internet technologies allow things to be sensed and controlled remotely across the existing network infrastructure.

In recent years, the Internet Objects (IoT) technology has been widely used to describe advanced solutions with different devices with computational ability and connected In the Internet. These solutions can be used in domains Such as Health, Agriculture, Smart Cities, and Industry including fields. Despite the fact that the term techniques processes relatively new, the idea of monitoring and controlling devices through computers and networks has been used for several decades, but it was limited within the network and it wasn't as wide as IoT proposed, as WSN have been used for sensing in the past it is the main component in the IoT, hence the IoT and WSN share the same challenges starting from security, privacy and ending in lifetime [1][2].

A Wireless Sensor Network (WSN) is a type of wireless ad hoc network that contain a large number of low-cost sensor devices spread over an area, where sensors report readings to a data collection destination (sink) or Base Station (BS), periodically or based on demand. The potential uses of this network range from military to medical applications. Their data can be as simple as measurements of physical parameters, such as temperature, pressure, relative humidity, etc. to as complex as multimedia content, as in recent years we have seen the researches of wireless video/visual sensor networks for a wide range of applications . Beside their memory capacity limitations, these low-cost sensors are limited in computation, communication capability and are usually battery-powered devices. Thus, such devices with limited resources require protocols that provide energy-aware routing [3][4].

As WSNs are deployed to collect and sense information for particular applications, energy-aware routing protocols are important parts since they help to increase the lifetime of any WSN network .A number of WSN Routing protocols have been proposed [5].

Routing Techniques Classified in WSN in Different terms, In Term of: Routing Processing, Network architecture, Network Operations in this paper the research team will focus on Network structure protocols, rely upon the architecture of network. Routing protocols in this category are distinguished on basis of nodes connections and technique they follow to transmit data packets from source to destination. This leads to following types of classifications as:

- Flat Protocol: The nodes are deployed evenly and have the same role i.e. each node is on the same level within the network. FLAT protocols can be categorized as: proactive, interactive, and hybrid protocols.

- Hierarchical Protocols: In these types of protocols, the nodes fall into clusters, and the node with the maximum power becomes cluster head. The cluster head coordinates the actions inside and outside the block. The cluster head is responsible for collecting data from cluster nodes and eliminating redundancy between collected data in order to reduce the power requirements for transmitting data packets from the cluster head to the base station e.g. LEACH, SEP, TEEN, APTEEN etc.

- Location based Protocols: Nodes are differed on basis of their location within the network. The distance between nodes is calculated based on the signal strength, the higher the signal, the closer the distance between them. Some protocols in this class allow the nodes to be in sleep mode, if no activity going on at the node e.g. GPSR and GEAR.

Among these categories of routing protocols of WSN, Hierarchical protocol is the best option for WSN lifetime constrains. The main aim of this paper is to improve hierarchical energy efficient routing protocols along with modifications over one of these protocols to get better lifetime for WSN. In wireless ad hoc network, there are huge numbers of routing protocols used for better energy consumption and operational life-time proposed in [6][7] [8] [9] [10].

ii. ROUTING CHALLENGES AND DESIGN ISSUES IN WSNs:

Even that, WSNs share many commons with wired and ad hoc networks, they also have a number of unique properties that distinguish them from the existing networks. These unique characteristics offer new routing design requirements that go beyond wired and wireless ad hoc networks. These challenges can be assigned to multiple factor including but not limited to:

i. energy capacity limitation: Since sensor nodes are powered by batteries, they have limited energy capacity. Energy is a big challenge for network designers in aggressive environments

ii. Limited hardware resources: beside, the limited energy capacity, sensor nodes have also limited capacity of processor and storage , therefore can only perform limited computational tasks. These constraints make many challenges in network protocol design for WSN.

iii. Data Aggregation: because the sensor nodes may generate significant repetitive data, similar packets from multiple nodes can be assembled and aggregated so that the number of transmissions is reduced. Data aggregation methods was used to achieve energy efficiency and improve data transfer in a number of routing protocols.

iv. Scalability: Routing protocols must be scalable in network size. In addition, sensors may not have the same capacity in terms of energy, processing, perception, and particularly communication. Thus, communication links between sensors may not be symmetric, in other words, a pair of sensors may not be able to have communication in both directions. This should be considered in the routing protocols.

There is more constrains and challenges that affect the design of Routing Protocol we mentioned the main and major constrains.[11] more details for routing challenges can be seen in [12].

iii. ROUTING PROTOCOLS IN WSNs

In designing of WSN routing protocols must take into account the challenges that mentioned in the previous section, to meet these challenges several routing protocol strategies have been proposed. One category of routing protocols uses a flat network structure where all nodes are at the same level (peers). The second category of routing protocols imposes Hierarchal network to achieve energy efficiency, stability and scalability. The third category of routing protocols uses the location in which the sensor node is processed [13]. Figure 1 summarize the taxonomy of WSN protocols in term of network structure.

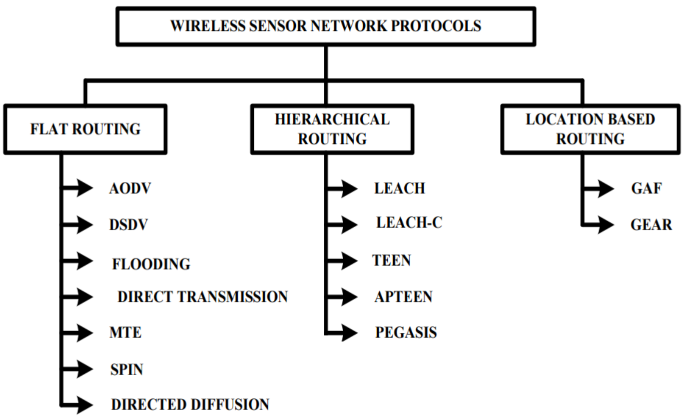

Figure 1: Taxonomy of WSN protocols in term of Network structure

A. Flat Routing Protocol:

In Flat Routing all nodes are considered peers. A flat network architecture has many advantages, including minimal overhead to maintain the infrastructure and the discovery of multiple routes between communicating nodes for fault tolerance. In this paper the research team will describe main flat routing Protocol:

a. Sensor Protocols for Information via Negotiation (SPIN)[14]:

The protocol was developed to improve classical flooding protocols and eliminate problems that could be caused, for example, explosions and interference. SPIN protocols are resources aware and resource adaptive. Sensors that operate on SPIN protocols can calculate the power consumption needed to calculate, send and receive data over the network. Thus, they can make informed decisions to use their resources effectively. SPIN protocols are based on two main mechanisms: negotiations and resource adaptation. SPIN allows sensors to negotiate with each other before distributing data to avoid injecting unreliable and redundant information into the network. SPIN uses metadata such as data descriptors that the sensors want to distribute. There is some improvement in SPIN protocol such as SPIN-2, SPIN-BC [14]. SPIN Protocol is the main protocol in flat category there is other protocol can be seen in [15] [16] [17].

B. Location-Based Routing Protocol

In Location-Based Routing protocols the site is used to address the sensor node. A location-based directive is useful in applications where the node's location is related to the geographic coverage of the network by the query from the source node. Such a request may indicate a particular area in which the phenomenon of interest may occur or proximity to a particular point in the network environment

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a. Geographic Adaptive Fidelity (GAF):

It is an energy-aware routing protocol, which is proposed primarily for MANET, but it can also be used in WSN, as it contributes to energy saving. GAF is stimulated by a power model that takes into account power consumption due to receiving and sending packets, as well as idle (or listening) time when the transmitter radio is turned on to detect incoming packets. GAF depends on the mechanism for turning off unnecessary sensors, while maintaining a constant level of routing accuracy (or uninterrupted communication between sent sensors). In GAF, the sensor field is divided into grid boxes, and each information sensor uses its location using GPS or other location systems can provide to connect to the specific network in which they are located. These links are used by GAF to determine equivalent sensors in terms of packet routing. Other Location-Based Routing protocols were proposed in [15] [16] [17].

C. Hierarchal Routing Protocol

In Hierarchal Routing protocols, network nodes are organized in clusters in which a node with higher residual energy, will be a cluster head where, the cluster head is responsible for coordinating activities within the cluster and forwarding information to the information sink (base station). Clustering has reduced energy consumption and extended the lifetime of the network in comparison with the flat and location-based routing protocols. In this paper the main Hierarchal routing Protocol will be discussed:

a. Low-energy adaptive clustering hierarchy (LEACH)[18] [19]:

Is the first and most popular energy-efficient hierarchical clustering algorithm for WSNs that was proposed for reducing power consumption .In LEACH, The nodes are divided into clusters where each cluster have a CH to aggregate data and report it back to the Base station instead of sending it directly to base station, these will reduce the possibility of collisions and the amount of data transmitted to the base station and make the network more scalable and robust. Leach have two phases (i) setup phase, where cluster heads (CHs) will be selected as each node will select a random number between 0 and 1 and if the number is greater than Trsh (n) it will be cluster head otherwise will be an ordinary node and the nodes that have been a cluster head before will not be elected once more.

$$Trsh(n) = \begin{cases} \frac{\rho}{1-\rho*(r \bmod \frac{1}{\rho})} & if\ n \in N \\ 0 & othwerwise \end{cases} \qquad (1)$$

Where ρ is the desired percentage of cluster head, r is the round number, N is the set of all nodes. After the CHs are elected they will send Advertisement requests and the network nodes will send join requests to desired CH and the clusters will be formed and CH will create a TDMA schedule for the current round. This phase were presented in [19] as flow chart in Figure 2.

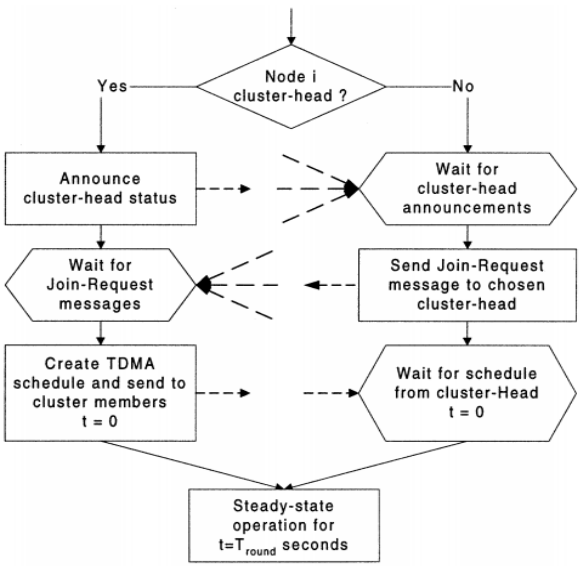

Figure 2: Flowchart of cluster formation algorithm for LEACH

(ii) Steady state phase, where the CH will send a TDMA schedule to cluster node where each node will send data on its TDMA slot and the CH will aggregates data and send it to the Base Station. There is many type of leach introduced in [10].

b. Power Efficient Gathering in Sensor Information Systems (PEGASIS):

The authors proposed a new Hierarchal routing protocol, where they aim. Firstly, to extend the network lifetime but distributing the energy consumption evenly over all nodes in the network. Secondly, to reduce the delay occurs in the other hierarchal WSN protocols where the data aggregate at specific node (usually cluster head) before being sent to the base station in this protocol the data sent directly to the base station. The authors assumed that nodes are deployed among an area of interest [20]. Where, all nodes have a global knowledge about all other nodes locations, in the first round the nodes will form a chain starting from BS to the closest neighbor till all nodes in the network are included in the formed chain as illustrated in Figure 3.

$$n0 \rightarrow n1 \rightarrow n2 \leftarrow n3 \leftarrow n4$$
$$\downarrow$$
$$BS$$

Figure 3: PEGASIS Chain

Even that experimental results the authors provided shows that PEGASIS outperform LEACH in a certain scenario's where, for example, if the data comes from the furthest node from BS that will cause a high energy consumption over the whole chain which will result that many nodes will die ,hence , decreasing lifetime.

c. THRESHOLD SENSITIVE ENERGY EFFICIENT SENSOR NETWORK PROTOCOL (TEEN) [21]:

Is a hierarchical routing protocol that combines sensors into clusters, each controlled by CH. The sensors in the cluster report their sensitive data to their CH. CH sends the collected data to CH at a higher level until the data reaches the receiver. Thus, reducing the transmitting time and increasing lifetime. However this protocol is not suitable for networks that require periodically update and information, since the user may not get any data at all if the thresholds were not reached. However, the authors in [14] presented a new routing protocol to overcome this issue called APTEEN. Other hierarchal protocol can be seen in [15][16] [17] [22].

vi. ENERGY AWARE PROTOCOLS :

Several algorithm were proposed for wireless sensor network to extended network life time using energy based algorithm, in this section many algorithms will be discussed. To illustrate and understand how these algorithms works the research team will present example model from [19] in Figure 4 , where the source node will be A and the destination will be H , the numbers on arrows will be the cost and the numbers over battery symbol indicate the current battery level.

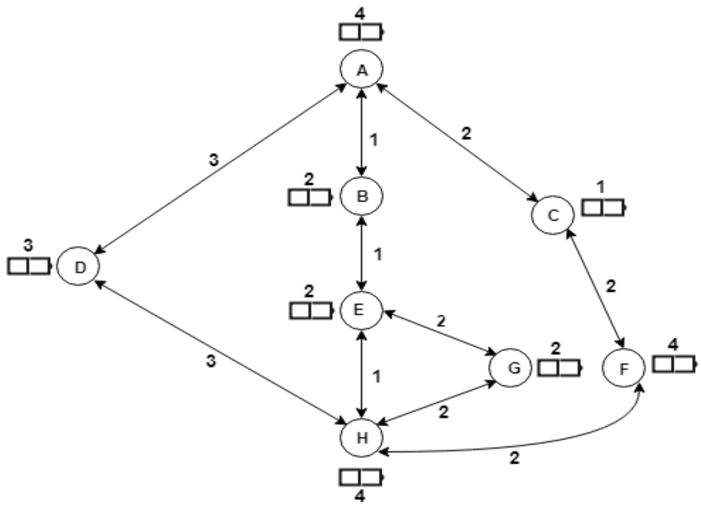

Figure 4: Example Model

a. Maximum Total Available Battery Capacity (MTAB) [8]

In MTAB, the route with the maximum total available battery capacity in nodes within that route, without taking needless Nodes, is chosen. Mathematically: let assume that the battery capacity at node i is denoted as B_i , and the routes to destination d is

$$r_d = r_0 , r_1 , \ldots , r_{N-1} \quad (2)$$

Where r_d is set of all possible routes to the destination, and N is the number of all possible routes. Then the function of total available battery capacity P in path L is:

$$P_l = \sum B_i \quad (3)$$

The optimal path will be the Max P_i in r_d. Table 1 illustrate how the optimal route is chosen in the example of Figure 4.

Table 1: MTAB Algorithm

Path Number	Path Hops	MTAB Value
1	A => D => H	3
2	A => B => E => H	2+2
3	A => B => E => G => H	2+2+2
4	A => C => F => H	1+4

The route 3 have a MTAB value of 6 which make it the max value within all other routes, however it will not be selected as there is extra needless hop (G) so eventually, the route 4 will be selected.

b. Minimum Total Transmission Power Routing (MTPR)

This algorithm make a simple metric of the route where it calculate the total energy consumed within route to reach the destination. Mathematically: let consider a generic route as follow: [9] [8].

$$r_d = n_0 , n_1 , \ldots , n_d \quad (4)$$

Where n_0 is the source node and n_d is the destination node, and the function:

$$P(n_i , n_{i+1}) \quad (5)$$

Is the energy consumed in transmitting in one hop. Then the total transmitting power over a route L is calculated using:

$$P_l = \sum P(n_i , n_{i+1}) \quad (6)$$

The optimal route will be the route with **minimum P Value**. Table 2 illustrate how the optimal route is chosen in the example of Figure 4.

Table 2: MTPR Algorithm

Path Number	Path Hops	TPR Value
1	A => D => H	3+3
2	A => B => E => H	1+1+1
3	A => B => E => G => H	1+1+2+2
4	A => C => F => H	2+2+2

As we see in the table the path with **Minimum TPR** value is the route 2 so it will be selected.

c. Minimum Battery Cost Routing (MBCR)

This algorithm were proposed to overcome one of MTRP disadvantages where only the transmission power is considered and the batter capacity at the node is neglected in the route selections , which will result to always select the route with minimum power transmission and the nodes at that route will die quickly. To overcome this, the remaining battery capacity of each node more accurate to define the lifetime of each node. Mathematically: let the battery capacity at node I at time t denoted as $B_i(t)$ then the battery cost function is [9] [8].

$$f_i(B_i) = \frac{1}{B_i(t)} \quad (7)$$

Then the cost of Route L is:

$$P_l = \sum f_i(B_i) \quad (8)$$

Then the optimal route will be the route with the **minimum P value**. Table 3 illustrate how the optimal route is chosen in the example of Figure 4.

Table 3: MBCR Algorithm

Path Number	Path Hops	BCR Value
1	A => D => H	1/3
2	A => B => E => H	1/2 + 1/2
3	A => B => E => G => H	1/2 + 1/2 + 1/2
4	A => C => F => H	1/1 + 1/4

As the path 1 have the minimum value of BCR it will be selected. A new algorithm were proposed to overcome the drawbacks of this algorithm , where the nodes with Minimum BCR still may select a route containing nodes with small battery capacity , hence these nodes will die. The new algorithm called Min–Max Battery Cost Routing (MMBCR).The author of [9] proposed new algorithm called Conditional Max–Min Battery Capacity Routing (CMMBCR), where if there are routes which all nodes have a battery level higher than a given Threshold then the route will be selected that required the lowest energy per bit, otherwise, the MMBCR algorithm will be used.

d. Maximum Residual Packet Capacity (MRPC)

As its difficult to know the optimal path unless the total packet stream is already known, and as the battery metric is not always the optimal metric to be considered the author introduced a new algorithm that select the optimal path based on both the residual capacity and expected energy dissipated during the transmission of forwarded packets over a specific wireless link. In other words, this algorithm take into account all metric proposed previously mentioned algorithms. Mathematically: let consider the Function of node-link metric be as [10]:

$$f_{i,j} = \frac{B_i}{P_{i,j}} \quad (9)$$

Where B_i is the battery and node i and $P_{i,j}$ is the transmission energy required by node i to transmit a packet over link(i,j). Then the Maximal lifetime over a route L can be presented as:

$$M_l = Min\,(f_{i,j}) \quad (10)$$

Then the desired Route will be the route with the **Max** $\boldsymbol{M_l}$ value. Table 4 illustrate how the optimal route is chosen in the example of Figure 4.

Table 3: MRPC Algorithm

Path Number	Path Hops	RPC Value
1	A => D => H	3/3
2	A => B => E => H	2/1
3	A => B => E => G => H	2/2
4	A => C => F => H	1/2

Then the route 2 will be selected. As it have the Max RPC value. The authors in [10] showed the MRPC last longer than the previously mentioned algorithm.

vii. Propose Work:

As discussed earlier the hieratical protocols are better than flat or location based routing protocols, and the LEACH protocol is the favorite among all hierarchal protocols where it is suitable, reliable and scalable unlike PEGASIS which outperform leach in term on lifetime under certain conditions but it has some drawbacks if the data being sent come mostly from furthest node in the chain from the base station. Or TEEN routing protocol which is not suitable for IoT where most of IoT application require frequently and periodically information updated. In our work we introduce a new version of LEACH protocol to overcome its drawback and to increase network life time as long as possible to be suitable and reliable over any circumstances occurs in the network.

As it's known that leach protocol is a one hop communication protocol either intra cluster or inter cluster. In our proposed model we modified the way the nodes communicate within cluster, instead of sending data directly to the CH the data will be sent through nodes in cluster until it reaches the CH. In order to make the multi-hop communications more energy efficient we used the best energy aware algorithm presented in (vi) and modify it to be suitable for use in leach protocol where there is no predefined links between nodes and CH, and the decision will be more accurate and better as it will be taken for each hop instead of all link. The modification where only in the communication intra cluster. The cluster head selection or communication with base station remain the same.

a. Energy model

The Energy model that was used is the same as presented in [18] [19], the Figure 5 shows the Radio energy dissipation model as the author in [18] [19] illustrated.

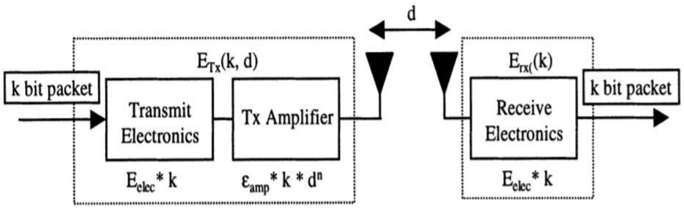

Figure 5: Radio energy dissipation model

The dissipated energy while transmitting will be as

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d)$$
$$E_{Tx}(k,d) = E_{elec} * k + \epsilon_{amp} * k * d^2 \quad (11)$$

Where k is the number of bits, and d is the distance between sender and receiver, and energy dissipated at the receiver side will be

$$E_{Rx}(k) = E_{Rx-elec}(k)$$
$$E_{Rx}(k) = E_{elec} * k \quad (12)$$

b. MAXIMUM RESIDUAL HOP CAPACITY (MRHC)

As in MBCR the $f_{i,j} = \frac{B_i}{P_{i,j}}$ where $P_{i,j}$ is the transmission energy required by node i to transmit a packet over link(i,j). In our proposed algorithm the decision will be made hop by hop so the $P_{i,j}$ represent the energy required to transmitting packet from one node to another via one hope communication and as illustrated in Equation(11) the energy dissipation in t relies on two parameter d which is the distance between the sender and receiver and k which is the number of data bits and as the bits are already the same but the distance varies the $P_{i,j}$ will be replace in our algorithm by the distance between the source node and the next hope. So the function $RHC = \frac{B_j}{dist_{i,j}}$ where B is the energy at the destination node and $dist_{i,j}$ is the distance between source and distention, the next hop will be the node in the same cluster that have the maximum RHC that satisfies the following condition:

First, the distance between source node and next hop is less than the distance between the source node and CH.

Second, the distance between source node and next hop is less than the distance between next hop and CH

If all nodes failed to satisfy these condition then the next hop will be CH, if no cluster head selected the next hop will be the base station. Mathematically:
Let assume that The MRHC will be applied to all $n_j \in N$
Where,
N: is the set of all nodes within cluster,
m: is the number of all nodes within cluster,
CH is the Cluster Head,
$\boldsymbol{n_i}$ is the source node,
CHD is Distance between the n_i and CH,
D is Distance between n_i and n_j,
NCHD is the distance between n_j and CH,
Next hop is the destination node.

The MRHC algorithm for a single next hop decision is illustrated Figure 6.

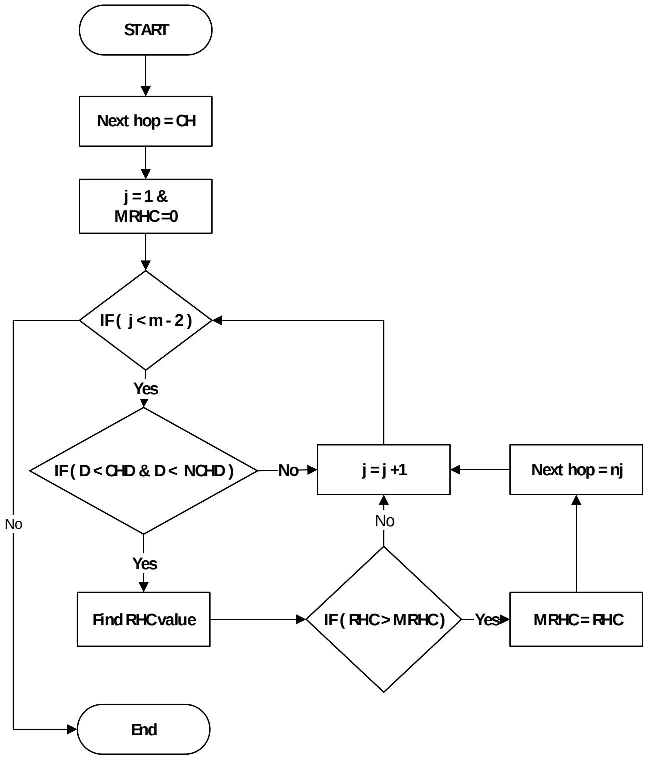

Figure 6: flowchart of MRHC algorithm

c. PSEUDO CODE

The pseudo code for the modified protocol will be as follow:

Step 1: Setup Phase

1. O_i choose r(0,1)
2. O_i compute Thre
3. if (r < Thre) The O_i become CH
4. else node will remain O
5. CH → N : id_H , Adv
6. O_i → CH : id_{O_i} , id_H , $Join\_Req$
7. CH → N : id_H , $(\cdots, < id_{O_i}, t_{O_i} >, \cdots)$, $Join\_Req$

Step 2: Steady State Phase

4. O_i → CH : $MRHC(d_{O_i}, id_H)$
5. CH → Bs : (id_H, id_{Bs})

Where CH is cluster head, O: ordinary node, Bs: base station
N: set of all nodes, MRHC: maximum residual hop capacity algorithm, and $(\cdots, < id_{O_i}, t_{O_i} >, \cdots)$ is the TDMA schedule

viii. RESULTS

Our proposed algorithm was made based on MIT µAMPS NS2 extension for LEACH project [23] using ns2.34 on ubuntu 10.04 LTS 32 bit operating system in VMware Workstation, all simulation parameters are summarized in Table 5.

Parameter	Description
Area Diminssions	1000 m X 1000 m
Number of Nodes	100
Mac protocol	Mac/802.11
Initial Energy	2 Joule
Channel Type	Wireless Channel
Radio Propagation model	Two ray ground
Antennae model	Omni antenna
Energy model	Battery
Simulation time	To Die
Topolgy	Heriarical , Random
Cluster Head Proportion	5%
Number of cluster heads	5
Routing protocol	LEACH , MRHC-LEACH

Table 5: Simulation parameter

To compare the new proposed protocol MRHC-LEACH, we modified MIT LEACH code, where the MRHC algorithm was added and modified in the receiving function as well. The results of the proposed protocol was compared with original leach protocol results under the same simulation parameter where the base station for both protocols was located at (50 ,175) , we have assumed that all nodes will start with equal energy all other parameters are summarized in Table 5 above.

In Figure 7, shows the comparison in term of energy dissipation for the whole network over the simulation time.

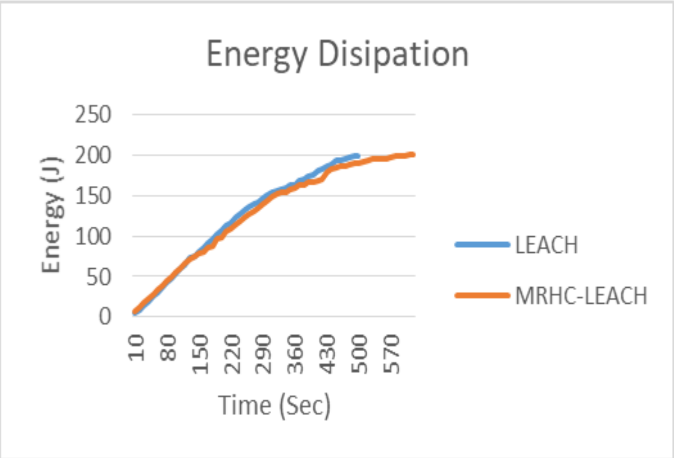

Figure 7: Energy Dissipation over Network lifetime

As shown in Figure 7 the results shows that the energy dissipation in the proposed work was increasing in a less rate than the original leach protocol as the communication within cluster in the proposed protocol increased the utilization of energy in the steady state phase increased. Hence, the energy dissipation decreased.

Figure 8, shows the network lifetime the new proposed protocol and original leach.

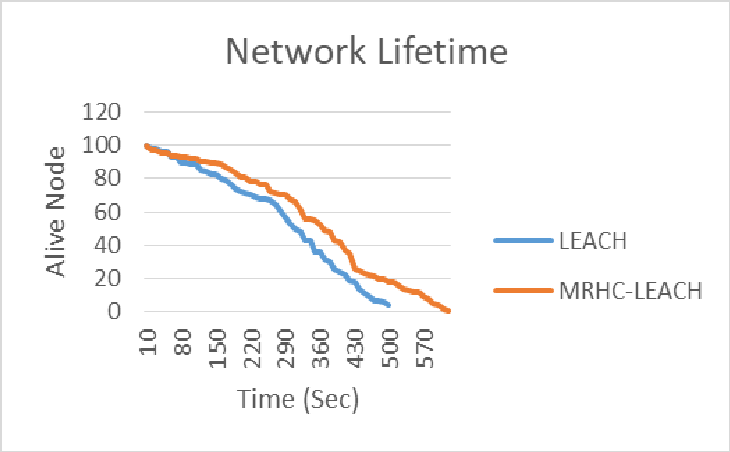

Figure 8: Number of Alive Nodes over the network lifetime

However, as the energy dissipation decreased in comparison to original leach. The number of alive nodes has increased in the proposed protocol .Figure 8 shows that the network lifetime has increased in term of lifetime, where the network lifetime in the proposed protocol was 614 second, in comparison to 495 second for the original LEACH protocol.

Figure 9, shows that total data delivered to the base station over the network life time.

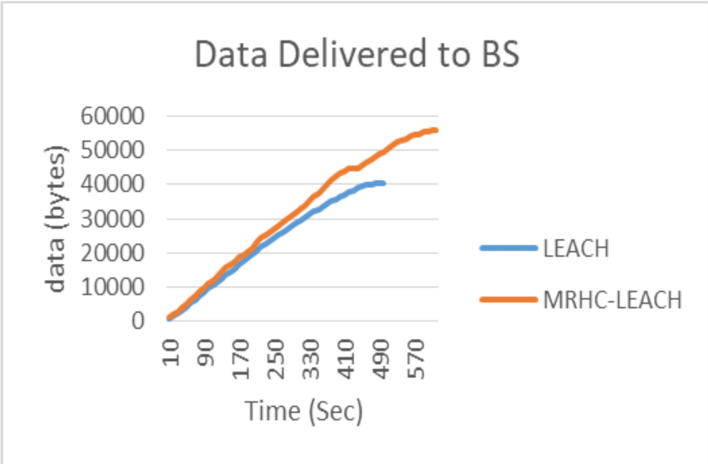

Figure 9: Data Delivered to Base Station over network lifetime

As shown in Figure 8 it's noticeable that the data sent to the base station is better in our proposed work in comparison to the original leach protocol, where the total data delivered to the base station in our proposed protocol was 55.9 Kbyte where it was only 40.5 Kbyte in the original leach.

ix. CONCLUSION:

In our paper, we proposed a new Energy-aware algorithm that we used to improve the communication between nodes and their cluster head where the communications were done in a single hop and the data sent directly to the CH, in our proposed algorithm we improve the communication to be multi hop where the data routed within cluster nodes till it reach the CH taking in account both the expected energy dissipation while sending data to the next hop, and the residual batter capacity in the next hop node.

The results showed that the new proposed protocol is suitable for the IoT application as the network lifetime increased by 24% compared to the original LEACH protocol without affecting the amount of data delivered to the Base Station, Even though , the data size increased by 38% compared to the original LEACH protocol. As a future work we can expand our algorithm to be applied to the communication between CH's and BS. Furthermore, as our work have solved the lifetime issue for IoT applications. Dividing the network into cluster and having intermediate nodes (CH's) between source nodes and Base Station would help to propose a new encryption technique that will be applied only at CH's before sending data to BS instead of applying the encryption all nodes.

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