Lecr: Less Energy Consumption Routing in Internet of Things

T. Julie Mary, A. Bhuvaneswari

***Abstract**: Internet of Things (IoT) constitutes a network of various devices has an equipment with the mandatory facility of communication and optional facilities of sensing, information collecting, storage and processing. IoT network has been used for research and development purpose in many application areas such as military environment, traffic management, and e-healthcare system. IoT network was enormous in scale and complexity, mainly in terms of energy efficiency because battery lifetime is limited. The previous routing protocols for IoT are difficult and require a huge memory use and high energy consumption which are insufficient for IoT network processing. For that reason, an efficient routing algorithm needed to decrease energy consumption while communication. To tackle this problem, this paper proposes Less Energy Consumption Routing (LECR) algorithm. This algorithm reduces energy consumption using 4 ways in IoT, (1) Sleep and Wake up Scheduling, (2) Route Discovery in IoT Base Station (3) Less Power Consumption Route for Communication (4) Reduce Overhead while Routing. The experimental result proves the LECR algorithm reduces IoT devices battery drain and increases lifetime of the IoT network efficiently.*

***Index Terms** : IoT, Energy Efficiency, Sleep Scheduling, Route Discovery, Packet Transmission.*

I. INTRODUCTION

INTERNET of Things is the technology that strives to interconnect and join all the devices within the same network. This is made possible by using Wireless Sensor Networks (WSN) which is the base in implementing this technique [1]. It is a technique which is normally utilized for identifying the system containing unique objects that can be identified which are naturally independent and hence will have the ability to get connected to the internet for presenting and exchanging real time data in a digital format. IoT has lots of similarities to Networked control System on the basis of Industrial WSN. This persist the WSN technology to be implemented in industries [2]. These devices usually contain sensors, processors, transceivers, energy sources, etc. for monitoring their environment and transferring the necessary data. It is used in a various fields like home automation, transportation, surveillance, healthcare, etc. [3]. The design of the devices depends upon its usage in the available equipment for WSN. In IoT, nearly all devices are battery powered. After the first deployment, these nodes are kept active without human control for a long time. Because of the nonexistence of any battery power efficiency techniques, within few days an IoT device would consume its whole energy.

Even in communication, lot of battery power is wasted in some reasons, such as collision, control packet overhead, interference etc. Hence with the purpose of reduce battery power consumption and enhancing the IoT lifetime, many routing protocols are already designed.

The traditional routing protocols such as AODV and DSR are implemented to discover just the shortest route [4, 5]. These routing protocols are not considered about devices battery power consumption. While routing, if a node chosen for relying frequently, it will be consume its whole energy. Due to this reason, the network lifetime may be finished. Furthermore, while route discovery, if all neighbor nodes frequently sends Route Request (RREQ) to one specific node which may be consume its whole energy. For this reason, the network lifetime will be over [6].

Furthermore, these routing protocols are relies hop count for shortest path selection. This metric is not suitable for IoT network. If any intermediate node drained its whole battery power, hop count based route discovery method may be failed. Furthermore, these routing protocols cannot reduce IoT devices energy consumption efficiently.

To deal with these problems, this paper proposed Less Energy Consumption Routing (LECR) algorithm for Internet of Things. This algorithm categorized into 3 sub-algorithms namely, Compute Direction and Distance algorithm, Estimate Energy Consumption algorithm and Packet Transmission algorithm.

This paper is structured as follows: Related works about battery power consumption discusses in Section 2. Less Energy Consumption Routing algorithm describes in Section 3. The results gets from simulation have been describes into Section 4. Furthermore, conclusions and future scope describes into Section 5.

II. RELATED WORK

In existing, many authors proposed energy consumption reduction techniques.

Cho et al. [7] focused on hierarchical intermediate node placing with battery power proficient path discovery method. It means, Wireless Sensor nodes are located in random style. Furthermore intermediate nodes are located in hierarchical style. Compared with other sensor nodes, the intermediate nodes battery power is high. These intermediate nodes are situated from sensor nodes, at a distance of one hop. They concluded hierarchical intermediate node placement consumes less energy. Santiago et al [8] proposed IoT network routing path discovery based on battery power efficient

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technique. They suggested transmission based technique using Cartesian distance to enhance routing for IoT networks and increased the life time of the network. The concept is applied to routing protocol which is mainly designed for constrained smart devices.

Mamoun Qasem et al. [9] suggested a technique for improve IoT lifetime that employed some children devices for the overloaded devices to guarantee device existence maximization. Furthermore, they mitigated any possible additional overhead.

Necip et al. [10] proposed a route discovery method based on available parent devices in IoT. Their method implemented based on number of Predictable Transmission and number of available parent devices to find the optimal route. First, their method compared all available parent devices and chooses least one as favored parent.

Sang et al. [11] proposed suggested EEPR (Energy Efficient probabilistic routing for IoT) algorithm with remaining battery power of all sensor nodes in AODV. Their algorithm controlled the relay request for avoid packet failure and IoT congestion.

Algimantas et al. [12] proposed the battery power considered protected Sockets Level Procedure which guaranteed the highest bandwidth and needed highest security with smallest battery power consumption. They clarified the Sockets Level Procedure fundamental conception and posed adaptive Sockets Level Procedure.

Amol et al. [13] presented the past research work and discussed the applicability towards the IoT. They discussed the existing route discovery method such as AODV, secure multipath routing protocol, energy aware ant routing, pruned adaptive routing and minimum battery power consumption routing protocols.

Belghachi et al. [14] used three types of route discovery metrics for parent node selection namely (i) available battery power of each nodes (ii) transmission delay (iii) ACO technique. They concluded that their proposed work was efficient than other existing routing path discovery techniques.

Vi Chien Thang et al. [15] suggested an algorithm to select the best path using two routing metrics such as forwarding nodes EI (Energy Indicator) and ETX (Expected Transmission Count). Oana et al. [16] first selected two metrics namely MinHop and ETX. Second, choose Link Quality indicator (LQI). They adopted a passive measurement technique. In that, they estimated the Packet Delivery Ratio using the existing data traffic.

Demirci et al. [17] proposed energy considered minimum hop routing path discovery algorithm in WSN. Their algorithm balance network load and ensure Bellman–Ford tree. Furthermore it finds suitable route based on routing path cost.

Rango et al [18] proposed the power considered multiple routing path technique with DSR protocol. Their technique [23] finds the shortest hop routing path with minimum battery power consumption of nodes.

Sun et al [19] presented a battery power entropy based multiple path route discovery algorithm. Their algorithm chooses dynamic multiple routing path based on entropy which decrease the routing path reconstruction issue while MANET nodes changes frequently. While packet transmission, their algorithm decrease MANET nodes power consumption.

Wu et al [20] proposed a game theory based route discovery protocol within the extremely autonomous MANET. Their protocol finds the smallest price of shortest route. They concluded that compared with existing [23] routing protocol, their protocol consumes less routing cost.

Zhu et al [21] proposed a route discovery algorithm namely PEER which enhance the MANET network performance. Their protocol decrease route detection overhead, end-to-end delay and MANET nodes battery power consumption.

Hemalatha et al [22] proposed two metrics for routing path discovery. One is dynamic and strong link between two nodes and another one is nodes battery power. They concluded that based on these two metrics their route discovery technique provided optimal path with a small amount of energy consumption.

III. LESS ENERGY CONSUMPTION ROUTING (LECR)

The Proposed Less Energy Consumption Routing algorithm categorized into 3 sub-algorithms, namely, Compute Direction Distance algorithm (Algorithm 2), Estimate Energy Consumption algorithm (Algorithm 3) and Packet Transmission algorithm (Algorithm 4).

Algorithm 1 explains the proposed LECR algorithm. The LECR algorithm initially form the IoT network based on Location List of IoT Base Station and IoT Devices. Furthermore, it sets all IoT devices to sleep mode. Followed by, it applies 3 sub-algorithms.

The first sub-algorithm compute Each IoT Devices, Direction and Distance value from IoT Base Station based on its geo-location values (x axis (Latitude), y axis (Longitude)) and Euclidean Distance.

Algorithm 1: Less Energy Consumption Routing (LECR) Algorithm

```
Input: IoT Base Station (IBS), IoT Devices (IoTs) with Initial Energy,
All IoT Devices with IBS Location List (LI)
Output: Less Energy Consumption Route (LECR)

IoT_Network_Formation(IBS,IoTs,LI)
Sleep_Scheduling(IoTs)
DirectDist[] = Compute_Direction_Distance(IoTs,IBS,LI)      // Algorithm 2
SortedDirectDist[] = Sort all IoT Devices Based on Direction and Distance
SDD[] = Sort once again including Single Direction
For each SrcIoT from IoTs
        Routes[] = Extract all available Routes for SrcIoT from SDD
        IE = Estimate_Energy_Consumption(R0)         // R0 - First Route
        LE = IE, LECR = R0                           // LE - Less Energy
        For each Route Ri in Routes do               // Ri Starts from Second Route
                Energy = Estimate_Energy_Consumption(Ri)      // Algorithm 3
                If(Energy < LE)
                        LE = Energy
                        LECR = Ri
                End If
        End For
        Wake_Up_and_Inform_about_LECR(SrcIoT)
        Sleep_Scheduling(SrcIoT)
End For
```


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$$d(P,Q) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

Based on Direction and Distance values, the IoT Base Station finds all available routes for each IoT devices. Algorithm 2 explains Direction and Distance Computation algorithm. Then it applies the second sub-algorithm for estimate all available routes energy consumption for each IoT devices. After that it extracts Less Energy Consumption Route for each IoT devices.

Algorithm 3 explains Energy Consumption Estimation Algorithm. Followed by, it applies third sub-algorithm for Packet Transmission. If any source IoT device sensing any kind of information, first wake up automatically and generates a packet. Furthermore, it wakes up all available IoT devices in its LECR. Followed by, it sends a packet via LECR. During LECR packet transmission, the intermediate IoT device maintains a Routing Table based on First-In-First-Out (Queue) format for reduce routing overhead. So the packet has been sent to IoT Base Station quickly without any routing overhead. After receiving an acknowledgement message from IoT base station, each IoT device in a LECR route setup to sleep mode. Algorithm 4 explains Packet Transmission.

Algorithm 2: Compute_Direction_Distance

```
Input: IoT Devices (IoTs), IoT Base Station (IBS),
       All IoT Devices with IBS Location List (LI)
Output: Each IoT Devices direction and distance details
        from IoT Base Station (DirectDist)

DirectDist[] = {}, i = 0

Loc1 = Extract Location of IBS from LI
x1 = Extract x1 from Loc1
y1 = Extract y1 from Loc1

For each Device Ni in IoTs do
        Loc2 = Extract Location of Ni from LI
        x2 = Extract x2 from Loc
        y2 = Extract y2 from Loc

        Direct = ""
        If (x1 < x2 && y1 < y2)
        {
                Direct = "NE";
        }
        Else If (x1 > x2 && y1 < y2)
        {
                Direct = "NW";
        }
        Else If (x1 > x2 && y1 > y2)
        {
                Direct = "SW";
        }
        Else If (x1 < x2 && y1 > y2)
        {
                Direct = "SE";
        }
        Else If (x1 == x2 && y1 < y2)
        {
                Direct = "N";
        }
        Else If (x1 == x2 && y1 > y2)
        {
                Direct = "S";
        }
        Else If (x1 < x2 && y1 == y2)
        {
                Direct = "E";
        }
        Else If (x1 > x2 && y1 == y2)
        {
                Direct = "W";
        }
                // Euclidean Distance
        Dist = Sqrt( (x2-x1)^2 + (y2-y1)^2 )
        DirectDist[i] = Ni + "#" + Dist + "#" + Direct
        i++
End For
return DirectDist
```

Algorithm 3: Estimate_Energy_Consumption

```
Input: Route
Output: Estimated Energy Consumption
EEC = 0
Let Er = k    // Er - required energy for receive packet (k jules)
Let Et = k1   // Et - required energy for transmit packet (k1 jules)
              // k and k1 are Threshold values
For each Device Ni in Route do
        Distance = getDistance(Ni, N(i+1))
    EEC = EEC + Er + (Distance * Et)
End For
Return EEC
```

Algorithm 4: Packet_Transmission

```
Input: Source IoT Device (SrcIoT),
       Less Energy Consumption Route (LECR),
       IoT Base Station (IBS), Packet
Output: Less Energy Consumed Packet Transmission

SrcIoT sense, wake up and generate a packet
IoT[]=Extract all IoT Devices from LECR

Send wake up signal to IoT[1]
For(i=1; i<IoTs_Length-1; i++)
        Receive wake up signal from IoT[i-1]
        wake up IoT[i]
        IF(i!=IoTs_Length-1)
                Send wake up signal to IoT[i+1]
        End IF
End For

SrcIoT transmit packet to IoT[1]
For(i=1; i<IoTs_Length-1; i++)
        Receive packet from IoT[i-1]
        Put packet to Routing Table
        Maintain Routing Table based on Queue format
        IF(i!=IoTs_Length-1)
                Transmit first received packet to IoT[i+1]
        ELSE
                Transmit first received packet to IBS
        End IF
End For

IBS Receive Packet from IoT[IoTs_Length-1]
Store Packet into its own storage
IBS Send ACK Message to IoT[IoTs_Length-1]

For(i=IoTs_Length-1; i>=0; i--)
        Receive ACK Message
        IF(i!=0)
                Forward ACK Message to IoT[i-1]
        End IF
        Sleep_Scheduling(IoT[i])
End For
```

IV. EXPERIMENTAL SETUP & RESULTS

This section presents the experimental results and discussions about LECR algorithm. This algorithm's simulation executed in java. After LECR algorithm implementation, it compared LECR with previous route discovery protocols namely MEA-DSR [18], SHM [17], EEPMM [19] based on the battery power consumption, routing path cost, and IoT Lifetime. First, this LECR algorithm's simulation placed 100 IoT devices in a 900m × 600m area. Each IoT device has a battery with 100 J initially. Furthermore, each IoT devices has radio waves transmission range is 100 m for communication. Energy Threshold for transmit a packet is 0.6 J and Energy Threshold for receive a packet is 0.4 J respectively.

A. Metrics for Evaluations:

To compare the performance of LECR algorithm with existing route discovery protocols 3 essential metrics used, namely,

1. Energy Consumption
2. Routing Cost and
3. Network Lifetime

1. Energy Consumption

In IoT network, each devices battery power consumed high while transmit and receive.

But these devices consumed less battery power while sleep. Energy Threshold for transmit a packet is 0.6 J and Energy Threshold for receive a packet is 0.4 J respectively.
If an IoT device sends a message to neighbor device, the IoT device battery power will be decreased (Eq. 2).

$$EnCon = Er + (D * PackSi * Et)$$

EnCon is the Battery Power Consumption of a IoT device in J; D is the distance between two IoT devices in m and PackSi is the size of a packet in Kb.

2. Routing Cost:

While packet transmission, suppose a relay IoT device consume 1 Joule, the routing cost is 0.05 Rupee (Threshold value). In this way whole route routing cost calculated.

3. Network Lifetime:

In IoT network, all IoT devices are active. If any IoT device consumes its whole battery power, that particular IoT device will be dead. So it cannot transmit any packet. Due to this reason, network lifetime is over.

Network Lifetime = First IoT device dead time – IoT network formation time (3)

B. Simulation Results:

Fig.1 demonstrates Proposed LECR with previous route discovery protocols comparison based on No of IoT Devices vs Battery Power Consumption Results. In MEA-DSR [18], SHM [17] and EEPMM [19] route discovery, an IoT device chosen for relying frequently, it will be consume its whole energy. In this circumstance these protocols are failed. Due to the reason of tackle these problems the proposed LECR algorithm consumes very less battery power.

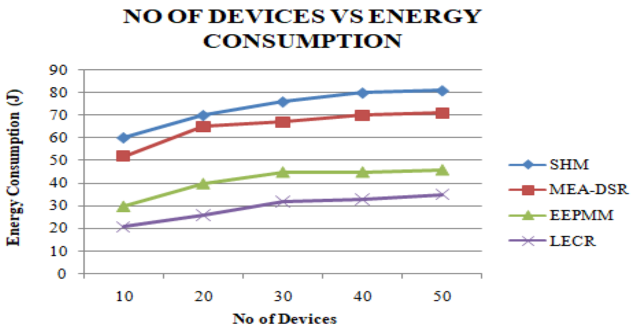

Fig.1 No of devices Vs Energy Consumption

Fig.2 demonstrates Proposed LECR with previous route discovery protocols comparison based on No of Devices vs Routing Cost Results. Compared with SHM, EEPMM [19], MEA-DSR, LECR has lower cost for Routing.

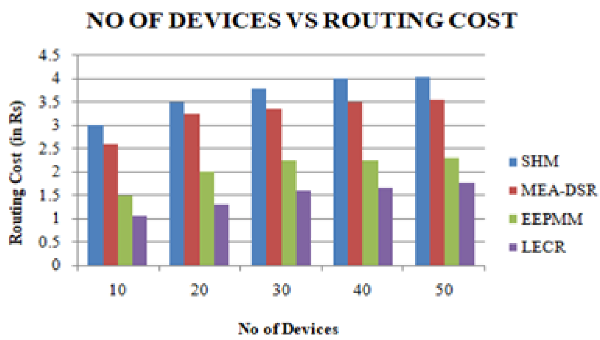

Fig.2 No of devices Vs Routing Path Cost

Fig.3 demonstrates Proposed LECR with previous route discovery protocols comparison based on Network Lifetime,. Compared with SHM, EEPMM [19], MEA-DSR, LECR enhance IoT network Lifetime well.

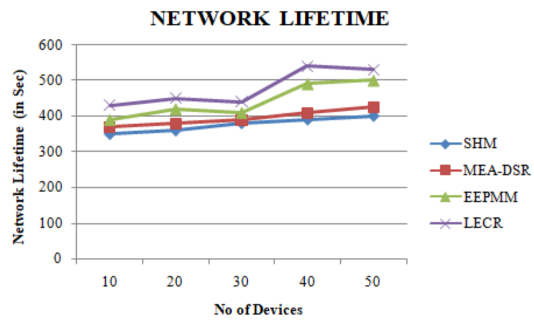

Fig.3 Network Lifetime

C. Sample Scenarios:

Fig. 4 shows IoT Network. This network contains one IoT Base Station with 99 IoT Devices.

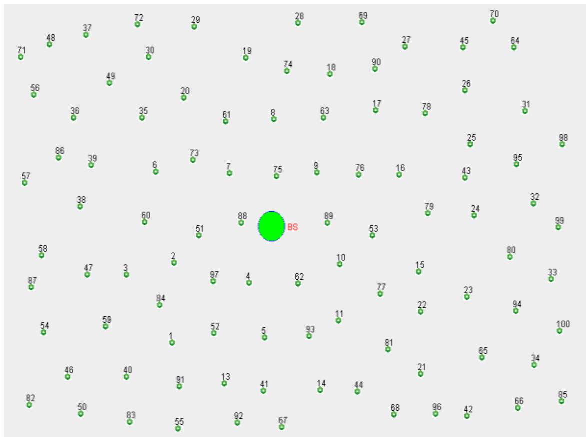

Fig.4 IoT Network with one IoT Base Station and 99 IoT Devices

Fig.5 shows Less Energy Consumption Route from IoT Device – 59 to IoT Base Station.

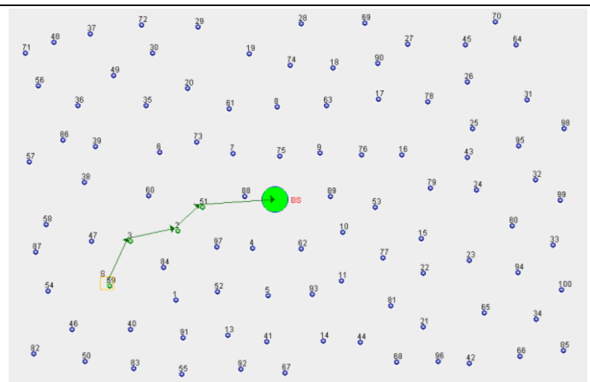

Fig.5 Less Energy Consumption Route

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V. CONCLUSION

This paper proposed Less Energy Consumption Routing (LECR) algorithm. To solve the high energy consumption problems, this algorithm applied sleep and wakeup scheduling for all IoT devices and finds all available routes based on direction with Euclidean Distance. Furthermore, this algorithm finds Less Energy Consumption Route based on Estimated Energy Consumption algorithm. The proposed LECR algorithm reduced routing overhead using Routing Table Maintenance based on Queue Format. Finally, simulation results demonstrated that the LECR algorithm enhanced IoT network lifetime, decreased battery power consumption and less routing cost while data transmission in IoT.

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