Linear Scalable Routing Protocol for Wireless Sensor Network

Poonam Rani¹, Avinash Sharma²

¹Research Scholar, Computer Science and Engineering, M. M. Engineering College, Maharishi Markandeshwar (Deemed to be University), Mullana, Ambala – 133207

²Professor, Computer Science and Engineering, M. M. Engineering College, Maharishi Markandeshwar (Deemed to be University), Mullana, Ambala – 133207

E-mail: poonamlabas.kuk@gmail.com

Abstract. Wireless Sensor Network (WSN) consisting of large number of low cost battery powered Sensor Nodes (SN’s) gaining attention of lot of researchers from past decade. Integration of SN’s with IoT devices results in large number of possible applications. Life of the network relies on the embedded battery & transmission of packets is major consumer of this limited power source. Lot of techniques exist in literature for effective utilization of this power source. This paper proposes a linear data communication scheme which can be scaled up/down as per the requirement of the application. Simulation results proves that scaling the network by increasing/decreasing nodes in same network area doesn’t impacts the lifetime of network, however if size of network is enhanced/shirked, correspondingly network life is also reduced/improved.

Keywords: Scalability, Routing, WSN, Wireless Sensor Network, energy aware.

1. Introduction

A (WSN) comprises of small, battery constrained SN’s interacting with one another via multi-hop remote connections and working together to achieve a typical job [1]. They are normally developed as empowering frameworks for digital physical applications that intently cooperate with outside improvement. Security, infrastructure checking, medical services, building or production line computerization are only few elucidative instances of how these developing innovations will affect our day by day life and society everywhere [2, 3]. SN’s are little miniature electromechanical frameworks (MEMS) gadgets [4, 5], working on restricted batteries for unavoidable processing [6] and IoT [7] which all around the world interconnect shrewd gadgets and sensor organizations. Along these lines, it gets basic to keep them useful as long as possible [8]. Communication governing protocols of PC organizations are not well-suited for vitality compelled remote sensor organizations. Every one of these protocols don’t think about the restricted memory and energy limit of the SN’s. In this way, plenty of proposals [9] are also available, explicitly customized to limit the vitality utilization of SN’s. These protocols are categorised into different categories [10].

The previous methodology incorporates many proposed techniques like DD [11], SPIN [12], LEACH [13], PEGASIS [14], TEEN [15], MSMTP [16], HEED [17] and so on. In flat steering, a SN by and large sends packets to neighbouring nodes inside its transmission extend. While in various routing a SN communicates its information to the closest cluster head (CH) which further transmits it to the sink. The two methodologies have some focal points and disadvantages. Establishing guideline of flat routing is agreeable via multiple nodes transmission, however in doing as such, an enormous amount
of data is produced and resulting in power consumption of numerous sensors. Though, in progressive routing plan, few assigned CH nodes liable for information collection from respective area individuals lastly sending the collected data BS. This rations the vitality of cluster individuals however observes a substantial cost for CHs [18, 19]. Additionally, because all SN’s will undoubtedly lock themselves to a CH, that can be accomplished by conveying via typical radio range. This further degrades QoS parameter [20] also, in turn results into reduced outcome.

2. Literature Survey
In WSN, after SN’s are sent, basic assignment of every SN is to send detected information occasionally to sink. The simple way to deal with accomplish this is sending data directly (DT), which permits SN’s to straightforwardly transmit to BS [13]. Nonetheless, it prompts jagged power consumption of the SN’s. So, this will create black hole problem, i.e. the nodes which are distant from sink would drain out faster than nearer nodes. The high difference in power utilization of sensors results in reduced network lifetime, harming the fundamental rules of WSN (viz., power preservation of SN’s).

To avoid such issues, Heinzelman et al. [13] proposed LEACH protocol, where area is partitioned into different zones, while system operation is partitioned into different rounds. Every round is additionally partitioned in 2 stages: first one is Setup and second one is steady state stage. In the first stage, every SN defines anon set by an arbitrary number. In the event that this irregular number has a lesser worth than the limit, it will choose itself as a CH. Each SN links itself to the closest CH, prompting a cluster formation. During second stage, CH totals the packets got from respective zone individuals and by following direct transmission, it transmits information to Sink. Hence it enhances system lifetime in a healthy multiple factor than that of DT.

M-LEACH [21] is the multi hop variant, where a CH send information to BS utilizing different CHs as moderate transmitters. Incorporated LEACH (C-LEACH) [22] is different variation of LEACH, where Sink is exclusively liable for set of clusters. TL-LEACH [23] is an augmentation of M-LEACH consisting of tree structures based on two levels (essential and auxiliary) of CH’s is framed. Essential CH’s get information data via SN’s, and optional CH’s, higher up in the ladder of command, get information packets from CHs bringing about expanded organization lifetime.

Progressively, HEED [17] creators present another strategy for choosing CH based upon two factors i.e. leftover vitality and correspondence cost. In requirement to have better version of the protocol, authors in [24] proposed a versatile grouping plot, which controls the CH race so that even burden on CH’s is guaranteed. Accordingly, each round is partitioned into 5 stages. When fix number of already defined CH’s are chosen, the round is finished, in any case the measure gets rehashed. This causes an extra postponement in the system as round termination takes delayed time. Second issue is the arbitrary determination of CH’s, which some time may avoid the ideal node for not taking an interest in the CH race measure.

Authors in [25] proposed HEER protocol, where CH determination is as done in [13], however as opposed to shaping the groups in each round, they are made just a single time, viz., during beginning of the communication process. This reduces delay as well as power utilization of the network. Subsequently forming the zone, a Hamiltonian way is built in each group prompting numerous virtual path in the system. In every cycle, SN with the most remaining power will be chosen as a leader for that round. In every round, virtual paths remain as it is however CH’s differ. This methodology makes them inadequacy; since group arrangement happens once for whole protocol activity, the achievement of this methodology relies upon how well and adjusted the groups are shaped.

Huynh et al. [26] propose another CH determination conspire where every node contends to turn into a cluster leader. The SN’s having the more remaining vitality are given inclination over less powered SN’s. When CH’s are chosen, groups are framed. It is defined as two-venture process; firstly, zone of nodes defined as clusters are shaped and in next step, CH’s are defined with their parent CHs. Defined parent gathers information from associated heads and sends it to BS utilizing transmission via multiple nodes.

In [28] authors proposed MLRC routing. It has three stages; CH selection, defining data transmission path and cluster arrangement. Every one of those SN’s having higher leftover power prominent as compare to normal vitality among residuals, go for Cluster Head election. They are chosen utilizing min-max standardization method by considering two variables, residual energy, and distance from BS.
When the CH’s are chosen they structure a course between each other to send data via multiple nodes to BS. Afterward, in cluster development stage, each remaining nodes hooks to any head node related to its proximity range with the destination within the existing cluster.

In developing the protocol, authors focus primarily on equal dispersed cluster thickness however in [29] author propose UCCGRA protocol, which proposes better way of clustering the nodes for WSNs. The fundamental aspect is that the group goes towards destination ought to uphold littler size of the cluster so that they spend smaller power while handling communicating among same cluster nodes and preserve higher vitality for the between cluster hand-off transmission. When CH’s are finalised utilizing associated chart hypothesis bury CH correspondence happens.

Subsequently to survive early power drainage CH’s, Lindsey et al. [14] proposed PEGASIS. Like the previously mentioned calculations, PEGASIS too works under operational reporting rounds. Toward execution of data transmission in each cycle, all SN’s essentially align the network by transmitting data in form of a chain along with one elected node being a pioneer. All SN’s link to their nearby neighbour and starts sending to the BS, in this manner lessening the measure of energy spent per round. In spite of the fact that it beats LEACH by 100–300% for network stable period, yet its reasonable deploy ability is certainly not a worthless assignment. PEGASIS depends on an unrealistic presumption that nodes have worldwide information on the network.

Authors in [30] proposed flat transmission based routing calculations for Gaussian. Afterwards, authors consolidated hybrid routing from combination of chain & tree based communication [31]. This technique was based on forming clusters among tree structured nodes so as to gain expansion in the network lifetime.

In GSTEB [32] creators constructed a solitary node as the root of the structure as opposed to choosing numerous CHs. On the start of every phase, BS communicates the identity of SN of the chosen root. Every deployed SN has just 2 other options; either to transmit to any other node in the network as next hop towards the root node otherwise transmit data directly to the root node.

TBC [33] is further improved version of [13]. At first, small fraction of nodes is chosen as CH’s proceeded by cluster development stage. In [13], every cluster part conveys legitimately to its head node, which prompts high energy scattering of those SN’s which lives a long way from the CH. To escape long connection transmission in every group, TBC isolates clusters in different levels. Node available in Lth level chooses the nearest node having a place with L-1 level. In the long run, inside every cluster a tree structure is maintain with CH placed at 0 level.

Authors in [34], proposed CEED, which is an upgrade of [13], essentially improving the CH determination as well as forming the clusters. In this technique, CH determination depends on remaining vitality and separation of every SN from the destination (BS). In cluster arrangement likewise, every SN picks its head on the premise of remaining vitality and gap. This protocol forms a chain among CH & remaining nodes for transmitting packets to sink.

3. Proposed System model
This section comprises of nodes/ Sink arrangement in the field, relevant assumptions and corresponding execution algorithms. Snippet of the MATLAB code is shown in figure 1.
3.1 Network model
This section describes uniform arrangement of SN’s in the field which are distributed at uniformly from over the area of interest. Sink is placed at central left side of the network as in [35]. However, it’s position can be set to any central side of the square as per requirement. Placing sink at centre of the network produce even better results. Corresponding arrangement is depicted in figure 2.

```
round=round+1
pkt_loss=pkt_loss+pkt_loss;
pkt_loss=0;
RemEnergy=0:pkt_rcvd=0;
for i=2:1:101
    if abc(1,8)<0.002 && abc(1,11)==9999
        pkt_loss=pkt_loss+1;
        count=count+1;  %dead nodes
        figure(2);
        xlabel('Dead Node Number')
        ylabel('Round Number')
        title('Round in which node dies')
        plot(count,round,'.')
        hold on;
        abc(i,11)=0;
        abc(i,8)=-9999;%Inactive node
        abc(count,12)-i;%id of node which is dead
        abc(count,13)=round;
        abc(count,14)=pkt_loss;%packet loss due to each node
    else if abc(i,8)>=0.002 && abc(i,11)==9999
        abc(i,0)=abc(i,0)-(abc(i,9)+abc(i,10));
        RemEnergy=RemEnergy+abc(i,8);
        tEnergy=tEnergy+(abc(i,9)+2*abc(i,10));
        pkt_rcvd=pkt_rcvd+1;
    end
```

Figure 1. Simulation Code
3.2 Assumptions
a. Nodes are stationary & placed at equidistant from each other.
b. Each node knows in advance the next node to which data is to be forwarded.
c. All the nodes are in close proximity of each other.
d. Data aggregation is performed at each level so as to eliminate redundancy of data.
e. Nodes are well aware of their location.
f. Data transmission is error free
g. BS is fixed & is placed on a particular position

3.3 Energy model
For implementing this proposal, first order radio model is referred.

4. Algorithms
For implementing the proposal, steps are defined in subsequent algorithms

4.1 Network Setup
a. Define the network area (x*y).
b. Place SN’s equidistant from each other (horizontally as well as vertically)
c. Place Base Station at (0, y/2)
d. Assign initial energy, transmission, receiver coefficient & electric energy to all SN’s.
e. Establish link between communicating nodes (flow of information)
4.2 Steady State
   a. Calculate distance of each node from the communicating (destination node).
   b. Based on distance calculated in previous step, calculate required transmission energy.
   c. Calculate receiving energy required by each node.
   d. For each round of operation
      i. Deduct transmission, receiving cost from total energy.
      ii. Keep check on sensor remaining energy
      iii. if sensor energy<dead energy, then discard node from network.
      iv. Keep count of packets lost during communication, round number in which a node stops operating.
   e. Keep on repeating step d, until number of discarded nodes=number of deployed nodes
   f. When all nodes are discarded, plot
      i. Residual energy of network (all sensors) during each round of operation
      ii. Packets lost in each round
      iii. Round number in which a node stopped operating

5. Result Analysis
Simulation of the proposed technique is done in MATLAB (R2014b 8.4.0, 64-bit version) on i3 processor machine with parameters as defined in Table 1. Proposed routing is simulated based on following network scenarios
Case 1: Network with 100*100 area, 100 Sensor nodes dispersed uniformly.
Case 2: Network with 100*200 area, 200 Sensor nodes dispersed uniformly.
Case 3: Network with 200*200 area, 100 Sensor nodes dispersed uniformly.

5.1 Network parameters
The proposal is simulated on the parameters as per basis of first order radio model & are defined in table 1

| Parameter                              | Value                |
|----------------------------------------|----------------------|
| Transmission and Receiving energy      | 50nJ/bit             |
| Amplification Energy for free space    | 10pJ/bit/m2          |
| Amplification Energy for multi path    | 0.0013pJ/bit/m4      |
| Nodes initial Energy                   | 0.5J/ 1J             |
| Packet Size                            | 2000 bits            |
| Number of nodes                        | 100/ 200             |
| Network Size                           | 100*100/ 200*200     |
| Base Station                           | (0,50)/ (0,100)      |
5.2 Network structure under different cases
As mentioned in previous section that proposal is tested under three different cases, corresponding variation in network structure is shown in figure 3.

![Network Structure](image1)

**Figure 3.** Network structure with scalability
As the network contains SN’s dispersed uniformly around the area, which leads to uniform dispersal of load on all nodes of the network. Each SN is computing the sensed information, aggregating the received data & then transmitting to next node. Due to this even distribution of load, whole network operates till end & then collapse altogether. Due to this, all packets are dropped at the same round as depicted in figure 4. Correspondingly, uniform decline in network residual energy can be easily observed in figure 5.
Figure 4. Packets Lost in each round of operation

Figure 5. Network residual energy with rounds
5.3 Lifetime of the Network

Network lifetime under three different cases with two energy levels (0.5J, 1J) is depicted in the figure 6.

![Network operational Rounds](image)

**Figure 6.** Network lifetime

Few observations from the figure 5 are:

a. Increasing node density over a particular area hardly affects the lifetime however data accuracy will be improved in this case.

b. Increasing number of nodes with proportionate to area (effective number same/meter²) will observe same network lifetime. However, data redundancy is reduced.

c. Increasing network size by same number of nodes will reduce network lifetime because nodes will communicate from larger distance also it will compromise quality of data too.

6. Conclusion

Large number of routing techniques are available in literature each with their own pros & cons. Linear routing technique proposed in this paper has high flexibility to scale up/down with the network with nominal effect on results. This dynamicity of the implementation makes it suitable routing technique for various applications. However, failure of node in between due to any reason (physical damage, manufacturing fault) may cause data loss of that chain, but data of network will survive that is retained on the other linear chains. So fault tolerance is also handled by the proposed technique.

7. References

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