Least Distance Smart neighboring Search (LDSNS) over Wireless Sensor Networks

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Abstract: - In this paper, we introduce a novel least distance smart neighboring search (LDSNS) to determine the most efficient path at one-hop distance over WSNs. LDSNS helps to reduce the energy consumption and speeds up scheduling for delivery of data. It provides cross layering support and linking MAC layer with network layer to reduce the amount of control messages. LDSNS is a robust and efficient approach that isbased on single-hop communication mechanism. To validate the strength of LDSNS, we incorporate LDSN in Boarder Node Medium AccessControl (BN-MAC) protocol [15] to determine the list of neighboring sensor nodes and choosing best 1-hop efficient search to avoid collision and reducing energy consumption.

Evaluation of LDSNS is conducted using network simulator-2 (ns2). The performance of LDSNS is compared with minimum energy accumulative routing problem (MEAR) [12], asynchronous quorum-based wakeup scheduling scheme (AQWSS) [14] and Minimum Energy Relay Routing (MERR) [13]. Simulation results show that LDSNS is highly energy efficient and faster as compared with MEAR, AQWSS and MERR. It saves 24% to 62% energy resources and improves 12% to 21% search at 1-hop neighboring nodes.

Keywords: LDSNS, Wireless sensor network, Energy consumption, MAC layer.

1. INTRODUCTION

WSNs is one of the prominent research areas in recent years. Unlike traditional networks, WSNs are particularly used in physical environments to develop high degree of perceptibility [6]. It is one of the rapidly growing fields with attractive features to use in several application areas[2], [3]. WSNs are considered as low-cost and easy to set up [4]. The advent of WSN has improved progress in surveillance and monitoring systems, home automation devices, earthquake and disaster applications etc. [1] & [5].

WSNs faces several design and performance issues such as waste of energy in idle listening, overhearing, extra control messaging, emitting and congestion. In addition, experiencing several performance impairing factors such as scalability, mobility, lack of robustness, uniformity etc. The energy consumption is considered as one of the major apprehensions [7] that stimulates challenges for industrial and academic sectors. Therefore, proper energy handling is one of the key skills to preserve energy [9].

The radio is the main power consuming section of sensor in WSNs that can be handled by introducing robust MAC protocols. Thus, an efficient MAC protocol improves WSN lifetime. In addition, MAC protocol has capability to handle the issue of sharing the wireless channel and reduces the collisions in order to improve throughput.

Several MAC protocols have been proposed to reduce energy consumption and to provide faster delivery of data but problems not fully yet resolved. Two types of mechanisms are used to support scheduling and routing the data: single hop and multiple-hop.

According to some protocols, a node takes a part in data union and consumes more energy. Since, the transmission of power is quadratically proportional to the distance, multi-hop approach consumes less energy than one hop communication, but it creates more overhead on the network and it also experiences severe problem when routes are broken. Furthermore, joining of new node and leaving of working node reduce the throughput and consumes sufficient amount of energy [10]. In this regard, one-hop communication is efficient and more reliable.

An energy-efficient minimum transmission energy consumption (MTEC) protocol is proposed to reduce the energy consumption and increase throughput during data transmissions. METC has also discussed that MAC protocol can dynamically adjust the size of contention window on basis of successful ratios of data transmissions using cross-layer protocol [8]. MEAR developed heuristic approach to determine an energy efficient wave-path and compared with traditional shortest path algorithm. The authors urged that the existing shortest path algorithm has shortcoming of optimal relaying strategy and channel propagation. MEAR also fisto decide which node should contribute in transmission schedule and the order of nodes to transmit and their transmission power [12].

AQWSS [14] introduced a set of asynchronous quorum-based wakeup scheduling mechanism to provide a better trade-off between average delay and energy consumption for neighbor discovery under variable environments.

MERR is introduced for linear sensor topology to consume less energy based on optimal transmission distance [13]. All of the discussed techniques try to reduce the energy consumption but from other side, they increased the overhead of network. Keeping these factors in mind, we introduce LDSNS approach to support BN-MAC protocol to reduce energy consumption and speed up the delivery of data without putting any extra overhead of control packets on network. The reminder of paper is organized as: section 2, explains the Least Distance...
Smart Neighboring Search (LDSNS). Section 3, simulation and analysis of result are discussed and the paper is concluded in section 4.

2. LEAST DISTANCE SMART NEIGHBORING SEARCH (LDSNS)

In LDSNS, any node monitors the channel after every 500 ms. Ifgain of channel is less than set threshold value, it shows that there is no activity on medium from its neighbor nodes; resulting that the node decides to sleep again. When a transmitter wants to communicate, it first sends short preamble to alert one hop neighboring nodes for sending the data. When the targeted receiversenses short preamble, it wakes up and responds with an acknowledgment (ACK) to transmitter. After the transmitter gets ACK, it starts to send the data packets. Pictorial illustration of the protocol is given in Figure 1.

Let us prove this idea by using Lemmas and definitions. The least distance smart neighboring search is based on 1-hop distance and route discovery. The designed WSN consists of different regions. The node which communicates within region that maintains local connectivity, whereas node that communicates out of region and schedules within region is called border node (BN). Let us assume that directed graph $D = (V, A)$, consisting of the set of sensor nodes V. The set of edges are called arcs that are $A \subseteq V^2$. It helps to differentiate between 1-hop destination and more than 1-hop destination nodes. The digraph distance between nodes is simply the number of shortest path between them [12]. We assign a name to each sensor node in V. A local route discovery method is based on relay scheme that works as follows.

For any destination node in ‘V’ specified by name ‘v’, the scheme targets the 1-hop destination nodes ‘u’ on basis of stored information in routing table regarding the shortest path 1-hop destination node. Each 1-hop destination node delivers the shortest path to its predecessor during exchange of control message. Finally, destination ‘v’ is acquired with efficient path. We apply method [8] for estimation of global technology of sensors by dividing nodes into routable boundaries and extracting adjacency associations between these boundaries. The objective of creating each boundary is to make the topology simpler, so that the searching process works efficiently within the boundaries. For a number of sensor nodes ‘V’ and communication digraph ‘D’.

We pretend that D is connected, thus we just consider connected components autonomously. Therefore, $u : (u, v) \in A$ can be denoted for hop count of neighboring search between ‘u’, ‘v’ in communication digraph.

**Definition 1.** Let P(x, y) denote set of paths from ‘x’ to ‘y’ for 1-hop neighbor nodes in direct graph (D_e). Hence, $S (x, y)$ is the distance (S) between two neighbor nodes x, y in D_e, which shows shortest path from node ‘x’ to ‘y’. It can be computed as:

$$S = (x, y) = L_{min}(p) \in p \in P (x, y)(1)$$

Where

L_{min}: Minimum length from one node to other node.

p: path value

If $D_e (x, y) = \emptyset$ then $D_e (x, y) = \infty$.

Therefore,

$D_g (x, \hat{E})$ between node ‘x’ and subset of nodes $\hat{E} \subseteq E$ that is defined as:

$$D_g = (x, \hat{E}) = \min D_g (x, y) \& y \in \hat{E} \hspace{1cm} (2)$$

Thus, $\hat{X}, \; \hat{E} \subseteq E$, be the distance between two neighbor nodes that can be computed as:

$$\min D_g (x, \hat{E}) \& x \in \hat{E} \hspace{1cm} (3)$$

Thus, we can add random infinitesimal for unique path.

**Definition 2.** For a digraph $D = (V_1, V_2)$, be the set of 1-hop destination nodes for vertex ‘v’ that is explained as:

$$\lambda - D(v) = \{ u : (u, v) \in V_2 \}$$

and beyond of 1-hop destination nodes are explained as:

$$\lambda + D(v) = \{ u : (u, v) \in V_2 \}$$

Where,

$\lambda$: Total number of neighboring nodes

D(v): Pair of one hop neighboring nodes

v: Value of link between two neighboring nodes

$V_1$: Vertex of node

$V_2$: Vertex of neighbor node

We describe 1-hop destination nodes of a vertex ‘V_1’ as union with set of 1-hop destination nodes vertex ‘V_2’. If the distance exceeds more than 1-hop destination nodes, it can be expressed as:

$$D_l (v) = \lambda + D(v) \cup \lambda - D(v)(4)$$

The range and out of range distance can be found as:

$$D_{range} (v) = \lambda + D(v)(5)$$

Above equation (5) shows that node is within range.

$$D_{Outrange} (v) = \lambda - D(v)(6)$$

![Figure 1: Mechanism of LDSNS to communicate with 1-hop neighbor nodes](image-url)
Equation (6) shows that node is out of range.

From equation (5) and (6), we deduce that

\[ D_{\text{range}}(v) \neq D_{\text{0-range}}(v) \]

We may again exclude subscript if digraph \( D_g = (V_1, V_2) \) is clear from context. The weighted graphs also get association of assorted length, cost and strength. We only focus on edge-weighted graph that is opposite to node-weighted graphs. We also need to restrict edge weights to 1 that yield an unweighted graph.

Consider digraph \( D_g = (V_1, V_2) \) and its subset for boundary of regions \( R \subset V_1 \), explain boundary \( B(v) \) of a node. Therefore, \( v \in R \) and whose nearest region is \( "v" \).

Thus, boundary of all regions can be expressed as follows:

\[ B(v) = \{ u \in V_1 | \forall w \in R, \lambda(u, v) \leq \lambda(u, v) \} \]  \hspace{1cm} (7)

**Lemma 1.** Let simple path \( P = (d, a_1, a_2, \ldots, a_e) \) that connects two region node \( d = a_1 \) and \( t = a_e \) with \( e \) edges and path of length is \( \lambda \). The related boundary path \( "P*" \) has maximum length in boundary dual graph \( B_g^* \) such as \( L(P^*) \leq e \cdot L(P) \).

**Proof:** The path includes \( e-1 \) that is used for more than 1-hop destination nodes and \( e \) edges that pass through \( e +1 \) multi-hop in the same region. The most of regions \( e+1 \) is intrusive regions, it means that original path does not go directly to those nodes but shortest path does. The \( L(P) \) in original graph is sum of edge weights that can be defined as:

\[ L(P) = d(s, t) + \sum_{i=1}^{e-1} w(a_i, a_{i+1}) \]  \hspace{1cm} (8)

Equation (8) shows the creation of path from transmitter to receiver. \( e \) is an edge between two nodes of boundaries on path \( P^* \) that is bounded as follows:

\[ P^* = [d', N_{\text{bound}}(a_i), N_{\text{bound}}(a_i + 1)] \leq N_{\text{bound}}(a_i) \]

\[ + W(a_i), (a_i + 1) \]

\[ + d((a_i + 1), N_{\text{bound}}(a_i + 1))] \]  \hspace{1cm} (9)

\[ N_{\text{bound}} : \text{Node in region} \]

\[ d^* : \text{Connecting two region nodes} \]

Let us assume that’s and ‘t’ be two nodes of region that could be source and target nodes, and defined as follows:

\[ d(a_i, N_{\text{bound}}(a_i)) \leq d N_{\text{bound}}(s, a_i) \]

\[ + d(a_i, N_{\text{bound}}(a_i)) \leq d(t, a_i) \]

It yields:

\[ (P^*) \leq d^*(s, t) = d^*(s, N_{\text{bound}}(a_i)) + \sum_{i=1}^{e-2} [d(N_{\text{bound}}(a_i), a_i + 1)] + W(a_i, a_{i+1} + d(a_i, N_{\text{bound}}(a_i + 1))] \]

\[ + d(N_{\text{bound}}(a_e - 1), t) \]

\[ \leq w(s, a_i) + d(a_i, N_{\text{bound}}(a_i)) \]  \hspace{1cm} (10)

Simplifying the equation (11), we get as:

\[ L(P) = e \cdot L(P) \]  \hspace{1cm} (12)

From equation (12), we see that Bound is observed to be tight because constructions exist.

For example, If any choice for \( \lambda > 0 \), thus edge graph weights of graph for two nodes of regions can be described as:

\[ d(a_i, N_{\text{bound}}(a_i) = m - \lambda, W(a_i, a_i + 1) = \lambda \]  \hspace{1cm} (13)

And

\[ W(s, a_i) = W(a_e - 1, t) = m \]  \hspace{1cm} (14)

Since \( 2m + (e-2) \lambda = \text{the length of path} \) and \( 2m + (e-2) \lambda = \text{the length of whole region} \).

Therefore, the worst case for \( \lambda \) can be written as:

\[ \lambda \rightarrow 0, \text{and ratio can be shown as follows:} \]

\[ \frac{LP^*}{LP} \rightarrow e \]  \hspace{1cm} (15)

If region nodes are available on shortest path, thus maximum expansion will be shorter than number of edges on shortest path. We hereby prove that maximum expansion is proportional to largest gap between region nodes on path.

**Lemma 2.** For any node \( u \in B(v) \), the shortest path from node \( u \) to \( v \) is completely included in \( B(v) \).

**Proof:** If lemma were incorrect, there would exist \( w \neq B(v) \) on the shortest path from node ‘u’ to destination node ‘v’.

Therefore,

\[ \lambda(w, y) < \lambda(w, u) \]

And such that:

\[ \lambda(x, y) \leq \lambda(x, w) + \lambda(w, v) < \lambda(x, w) + \lambda(w, u) = \lambda(x, u) \]  \hspace{1cm} (16)

This statement contradicts with hypothesis, such as \( x \in B(u) \); thus lemma must be correct. One inference of this lemma is connection of boundary cells on spanning graph. Region cells are dirichlet, connecting all points of sensor field. Region has simple topology in all dimensions that is stronger point of connectivity. The simpler topology helps to make subsets of sensor fields, when sensor filed experiences large holes. Thus, edges \( u_1, u_2 \in B(v) \).
Lemma 3: For node in each region of WSN calculates maximum cost for all one-hop neighboring nodes for selection of lowest cost path.

Proof: Let ‘x₁’ be node, which calculates the cost for each 1-hop neighboring nodes ‘x₂’. Here, ‘T_cost’ is total cost for all 1-hop neighbor nodes and ‘S_cost’ is the cost for one neighbor node, which can be calculated as follows.

\[ T_{\text{cost}} = S_{\text{cost}}(x_1) + S_{\text{cost}}(x_2) + \text{Level}(x_1,x_2)(17) \]

We set value zero to T_cost(x₁) because ‘x₁’ is initiating node that calculates the path cost that will be starting point. Energy Level is used to calculate transmitting and receiving cost of node with remaining energy of nodes. Nodes with value of high cost are discarded and the cost of each 1-hop neighbor node is saved into routing forwarding table (RFT).

Thus, ‘x₂’ calculates the minimum cost distance ‘D’ for reaching at 1-hop destination node with RFT using following formula.

\[ S_{\text{cost}}(x_1) = \sum_{k \in \text{RFT}} D_{x_1,x_2} \times T_{\text{cost}}(18) \]

It is proved that minimum cost for establishing path from ‘x₁’ to ‘x₂’ is set in RFT of ‘x₁’.

3. SIMULATION AND ANALYSIS OF RESULT

The Realistic environment of WSNs use low power radios with stochastic link and high asymmetrical communication range. The simulation results could be different from expected realistic results. We simulate LDSNS, MEAR, AQWSS and MERR using NS 2.35-RC7. For simulation, we have designed WSN that consists of different regions. Each region has boarder node (BN) that forwards the collected information of its region to BN of next region. We have simulated different realistic scenarios: mobile and static. The main goal of contribution is to reduce energy consumption and supporting faster search at one hop neighbor nodes.

The simulation scenario consists of 140 nodes with transmission radius of 30 meters. The Bluetooth enabled (BT) sensor nodes are uniformly and randomly placed in geographical area of 300 * 300 square meters. Area is divided into 75m x 75m different regions. The initial energy of nodes is set 40 Joules. The bandwidth of node is 50 Kb/Sec and maximum power consumption for each sensor is set 16 Mw. Sensing and idle modes 12 mW and 0.5 mW respectively but in our case, there is no idle mode. Sensors either go to active or sleep mode. Each sensor is capable of broadcasting the data at 10 power intensity ranging from -20 dBm to 12 dBm.

Total simulation time is 35 minutes and set 30 seconds pause time for initialization of phase at start of simulation. During this phase, only BN remains active and remaining sensors of all regions go into power saving mode automatically. The results demonstrate an average of 10 simulation runs. The energy consumption pertaining with different radio modes and simulation parameters are summed up in Table 1.

Table 1: Summarized simulation parameters for WSN

<table>
<thead>
<tr>
<th>Name of parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission Range</td>
<td>30 meters</td>
</tr>
<tr>
<td>Type of sensors</td>
<td>BT node sensors</td>
</tr>
<tr>
<td>Sensing Range of node</td>
<td>10 meters</td>
</tr>
<tr>
<td>Initial energy of node</td>
<td>40 Joules</td>
</tr>
<tr>
<td>Bandwidth of node</td>
<td>50 Kb/Sec</td>
</tr>
<tr>
<td>Number of sensors</td>
<td>105 BT node rev-3</td>
</tr>
<tr>
<td>Size of network</td>
<td>300 * 300 square meters</td>
</tr>
<tr>
<td>Size of each region</td>
<td>75 * 75 square meters</td>
</tr>
<tr>
<td>Packet transmission rate</td>
<td>30 Packets/Sec</td>
</tr>
<tr>
<td>Mobility model</td>
<td>Random way-point</td>
</tr>
<tr>
<td>Simulation time</td>
<td>35 minutes</td>
</tr>
<tr>
<td>Initial pause time</td>
<td>30 Seconds</td>
</tr>
<tr>
<td>T_s energy</td>
<td>16 mW</td>
</tr>
<tr>
<td>R_e energy</td>
<td>12 mW</td>
</tr>
<tr>
<td>Power intensity</td>
<td>-20 dBm to 12 dBm</td>
</tr>
<tr>
<td>Start time of BN-MAC</td>
<td>(0,30) Seconds</td>
</tr>
<tr>
<td>Sink location in each region</td>
<td>(60, 40)</td>
</tr>
<tr>
<td>MAC protocol</td>
<td>BN-MAC</td>
</tr>
<tr>
<td>Type of protocols</td>
<td>MEAR, LADSNS, AQWSS and MERR</td>
</tr>
<tr>
<td>Mobility</td>
<td>0.5 m/sec to 3.5 m/sec</td>
</tr>
<tr>
<td>Size of packets</td>
<td>8, 16,32,64,128,256 and 512 bytes</td>
</tr>
<tr>
<td>Routing Protocol</td>
<td>Pheromone termite</td>
</tr>
</tbody>
</table>

To demonstrate the validity of this novel environment of WSN for handling several devices, we conduct several tests from different perspectives. Having proved the mathematical model, let us now evaluate the efficiency of WSN.

We target preserving amount of energy of the network after deploying from sensors as shown in figures 2 to 6. Our simulated network shows that our proposed paradigm achieves almost 100% efficiency and saves 62% energy using maximum 140 sensors. We establish 15 sessions simultaneously in order to determine the actual behavior of the network in a highly congested environment. If we have less number of sensors, it is hard to establish many sessions at the same time. Figure 2 shows 14 hops in WSN and the used duty cycle. We note that LDSNS has consumed minimum duty cycle as compared with MERR, MEAR and AQWSS. During 1 hop destination, all of the techniques use 1.5% to 2.0% duty cycles as the hops increase then their consumption ratio of duty cycles decrease. The reason is that there is no overhead on single hop-node and work is distrusted on other nodes that are part of other hops. LDSNS uses less duty cycle because it is integrated with BN-MAC protocol that has fully support of semi synchronous mechanism as well as robust nature of LDSNS makes it capable to use low duty cycle.
In Figure 3, we show consumption of energy for each scheme against variable size of packets. LDSNS consumes less energy with variable size of packets. In case of broken link, LDSNS uses alternate link to send data packets but other schemes do not have sound alternate link to forward the data. Further, LDSNS uses both proactive and reactive approaches, when nodes are static and there is possibility of leaving and joining the new node. If the node decides to leave or other node wants to join then LDSNS uses reactive approach to get run time information according to change of topology.

In Figure 4, we show consumption of energy versus number of hops. LDSNS consumes less energy than MERR, MEAR and AQWSS. The increase in the number of hops affects all protocols but LDSNS has better energy consumption. LDSN is based on an efficient approach which integrated mobility and scalability aware BN-MAC protocol. Meanwhile, the other approaches experience energy increase due to the limited support at MAC layer.

In Figure 5, we show the effective duty cycle versus the number of neighboring nodes. Due to the increase in the number of neighbor nodes, LDSNS, MERR, MEAR and AQWSS are affected. Meanwhile LDSNS is not highly affected. In addition, LDSNS is supported with semi synchronous approach inherited by BN-MAC protocol. In all
of cases, LDSNS performs better than other protocols and consumes less energy and gets higher data packet rates.

4. CONCLUSION

In this paper, we have introduced the Least Distance Smart Neighboring Search (LDSNS) to reduce energy consumption and provide faster scheduling for data delivery. LDSNS performs better than other techniques even under low duty cycle and different packet sizes. LDSNS is integrated with BN-MAC protocol to support several applications such as disaster, home automation, hospital and monitoring applications of WSNs. To test the strength of LDSNS, our designed WSNs divided into N-regions. Each region consists of one border node that communicates with a neighboring region. The boundary node is randomly elected on the basis of high energy available in the node. To validate the proposed LDSNS, we have simulated LDSNS and compared its performance with other known protocols: MEAR, AQWSS and MERR by using ns2.35-RC7. On the basis of simulation results, we demonstrate that LDSNS performs better than other mechanisms (protocols) in terms of low duty cycle, energy consumption, increasing number of neighbor nodes and size of packets. LDSNS saves 24% to 62% energy resources and improves by 12% to 21% search at 1-hop neighboring nodes. In the future, we plan to combine LDSNS with different analytical models to test its strength in different scenarios.

REFERENCES