WP – A Tree Based Response Time Algorithm for Event Driven Wireless Sensor Networks

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ABSTRACT

Irrespective of the deployment strategy or the coverage constraints, the usual energy conservation inevitability remains. Among the many approaches that have come up so as to save energy, reducing the number of transmissions and an effective routing strategy accomplish consideration. In addition to the number of transmissions, the response time and average delay become critical when referring to an event driven sensor network. This paper is an effort to reduce the burden of existing routes, neutralize the hot spots for a balanced and uniform energy depletion of sensors as well as a better response time in order to increase the effectiveness of the network as a whole. A Parallel approach to reduce the overhead of individual sensors thereby ensuring a uniform depletion of the nodes has been proposed without compromising the energy and network constraints.

Keywords: Sensor Network, Tree Hierarchy, Energy conservation, Response time.

1. INTRODUCTION

A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, turbidity, humidity, etc. As an advantage, there is no need of physical connections among nodes to communicate with each other in a WSN [1]. The sensors cooperatively pass data through the network to a main location i.e the base station. The main function of sensor nodes is to collect and send data to sink nodes which are connected to computing devices and external networks [2, 3].

An event driven wireless sensor network is a specialized network that detects any anomaly in the condition under observation and informs the base station within the real time constraints. In addition to sending periodic observations, the sensing node reports the event through messages on any event of interest. For the purpose, some Intelligency for signal processing and networking of data is incorporated in the sensor nodes.

Among the varied quality of service requirements in a wireless network, response time is one of the cost measures to judge the quality of a distribution strategy. Optimal response time is crucial when going for query processing in a sensor network analogous to a distributed system.

The parameters affecting response time are

- Type of network maintained,
- Access of data: local or remote,
- Process of communication: serial or parallel,
- Lifetime and energy constraints,
- Communication speed, memory and bandwidth
- Propagation technique.

We discuss the related work in Section 2, the effect of balanced and unbalanced tree hierarchy in Section 3, present the system model and describe WP approach in detail in Section 4. The description of experimental evaluation follows in Section 5 and a summary and conclusion of work in Section 6.

2. RELATED WORK

The response time of a sensor node gets affected by collisions in data packets. The balancing of the node degrees results in minimization of packet collisions during query execution. The Minimum-Hot-Spot query routing trees [1] achieves tree balancing for a distributed algorithm that is much closer to the centralized algorithm. The algorithm utilizes Coefficient of Variance (COV) parameter and a sequential greedy parent selection strategy. The average response time of the whole network can be reduced by incorporating balanced load strategy so that the energy usage of each node is almost equal and average lifetime of the network is increased [4]. A decisive variable for prolonging the longevity of a WSN is to minimize the utilization of the wireless communication medium. It is well established that communication over the radio in WSNs is the most energy demanding factor among all other functions, such as storage and processing [5].

In utilizing multiple paths for responding an event by the sensor node, the multiple copies of the same packet may be travelling along different paths in parallel towards the same destination due to which duplicity is incurred [6]. An alternative to the method is to choose to create multiple possible paths, but use only one of them at a time [7], whereas other works have focused on in-network data processing as a means for energy saving [8]. For example, the utilization of PERLA as a data gathering protocol for wireless sensor networks employs a hybrid single/ multi-path routing algorithm which makes use of alternative paths when necessary [7].
The proposal of ViTAMin [9] constructs a virtual backbone tree using the characteristic distance. It connects a non-tree node to a tree node which guarantees the minimal energy consumption to transmit data to the sink node. This results in a minimum packet collision in the network, hence optimizing the response time of nodes. With characteristic limitations of a sensor node and need to satisfy real time response constraints, the need of a parallel distribution scheme is required. It can be service based architecture [10] for designing sensor networks, where the data communication functionality is separated from the application-specific processing, or an implementation of a multi-radio WSN platform [11], where simultaneous data exchange with multiple neighbors can be used for minimizing hop delays and for maximizing network throughput.

Although random placement is considered to be the ultimate long term goal, it is currently infeasible in most situations as the individual sensors are generally too expensive to deploy in an environment where the probability of destruction of nodes during deployment is high [12]. Random deployment of nodes can be augmented with deterministic features to achieve finer placement pattern.

In this paper, we introduce a distributed algorithm, coined Weighted Parallel (WP) algorithm that uses parallel transmissions and load balancing in order to almost equalize the energy consumption of each sensor node, which minimizes the collision in network. WP explains a hierarchical communication with optimal query forwarding on the basis of selection probability and weights and has been found successful in reducing both the average response time and average energy of consumption.

3. EFFECT OF BALANCED VS UNBALANCED LOAD

It requires a robust strategy to communicate across the network with the minimum overhead with the usual constraints like energy. The event driven WSN has an advantage that for large applications, it requires fewer messages to be transmitted. In order to process continuous queries in an event driven WSN, a data acquisition framework is maintained that organize sensors in a tree hierarchy (T). This hierarchy provides each sensor with a path over which the sensed data is transmitted to the sink node. In the current scenario, T is constructed in an ad-hoc manner; hence there is no guarantee of distribution of workload equally among the nodes in the network [12].

The unbalanced workload poses three major challenges: i) Increase data transmission collision; ii) Wastage of energy due to unnecessary collision; iii) Reduction in network lifetime; since most of the energy is spent on transmitting and receiving data, the node with higher workload will be depleted more rapidly than others; iv) Reduced coverage of the sensor nodes, resulting in undesirable response time of the nodes; in absence of alternate parents, the nodes whose parent has depleted will have lesser or no coverage.

4. SYSTEM MODEL

We formalize our system model and the basic terminology that will be utilized in the subsequent sections. We give formal definitions and propositions that we use in our algorithms and use to define the optimized response time.

Let V denote a set of n sensing devices \( \{v_1, v_2, \ldots, v_n\} \) in an Event driven wireless sensor network. Let \( T = (V, E) \) denote the network tree that represents the communication edges E of the nodes in V. The nodes are considered neighbors if they are within communication range. The sensor nodes are deployed using QRA. The QRA uses Quasi Monte Carlo Integration strategy for calculation of coordinate values. The discrepancy sequence utilized is Halton sequence that is multi-dimensional in implementation. Thus, the nodes are deployed with their unique nodeID and are location-aware.

4.1 Assumptions

Assume that the nodes have a restricted communication range. In this case, a routing tree T is created connecting every node over a multi-hop path with the sink. Each node has its local depth (d_v) and branching factor (the number of children to accommodate) known to itself.

**Definition 4.1.1:**

Given a tree \( T = (V, E) \), an edge \((u, v) \in E\), and range \( R \) of a node, then a node \( S_i \) will be the child of node \( S_j \) if and only if \( S_j \) is in range of \( S_i \), where \((S_i, S_j) \in V\).

The hierarchy tree generated will be balanced in order to minimize the number of collisions during transmission across the network.

**Definition 4.1.2:**

A tree \( T \) is balanced if and only if all the nodes in the tree has number of children less than or equal to the branching factor. Each node is associated with energy \((J)\) in Joules, with each path among nodes is assigned a weight \((W)\) parameter.

The response time is calculated (as shown in Fig. 1.) on the basis of the most eligible link to transmit that is computed dynamically on comparison of the distance from the randomly generated events and the minimum weights that are assigned to each connecting link as a measure of energy conserving criteria.
4.2 Notations

Table 1: List of notations.

<table>
<thead>
<tr>
<th>Notations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>total number of nodes deployed</td>
</tr>
<tr>
<td>S_i</td>
<td>set of all nodes deployed</td>
</tr>
<tr>
<td>(X_i, Y_i)</td>
<td>coordinates of i^th node</td>
</tr>
<tr>
<td>Node_ID</td>
<td>unique identification of each node</td>
</tr>
<tr>
<td>T_i</td>
<td>tree generated using node communication</td>
</tr>
<tr>
<td>i. level</td>
<td>level of node i in tree hierarchy</td>
</tr>
<tr>
<td>i. parent_distance</td>
<td>distance of node i from its parent</td>
</tr>
<tr>
<td>R</td>
<td>response time</td>
</tr>
<tr>
<td>ED_i</td>
<td>Euclidean distance between i and j</td>
</tr>
<tr>
<td>APL</td>
<td>alternate parent list of a node</td>
</tr>
<tr>
<td>B</td>
<td>optimal branching factor</td>
</tr>
<tr>
<td>W_i</td>
<td>weight of path between a pair of nodes</td>
</tr>
<tr>
<td>E_i</td>
<td>set of events</td>
</tr>
<tr>
<td>cost</td>
<td>transmission cost of a node</td>
</tr>
<tr>
<td>D_i</td>
<td>Euclidean distance between an event and sensor node</td>
</tr>
</tbody>
</table>

4.3 Algorithm

/* Deployment of nodes*/
1: Begin procedure waltz_deploy (n, b_i; where (b_i є smallest prime number set)).
2: For i=1 : n repeat
3: Compute coordinate: call (halton (i, b_i)).
4: End procedure.

/* Tree generation*/
1: Begin procedure waltz_tree (S_i, (X_i, Y_i); where (S_i є set of nodes)).
2: Initialize i:=0, j:=1, range of each node:= range.
3: While (i < n) do
4: While (j < n) do
5: If (j ≠ i and i. parent ≠ NULL) then calculate ED (i, j)
6: If ED (i, j) < = i. range) then
7: If (j. parent = NULL) then
8: Assign parent to node
9: Else assign the alternate parent list (APL) to the node.
10: End if.
11: End if.
12: End if
13: End while.
14: End while.
15: End procedure.

/* Response Time Calculation*/
1: Begin procedure waltz_response (T_near_balanced, R).
2: Initialize i:=0, j:=1, W_i:=0, cost:=1; where (W_i є weight of each connected path; cost є transmission cost).
3: While (i < n) do
4: While (j < n) do
5: Calculate ED (i, j).
6: End while.
7: For each event E_i, calculate ED (E_i, node_ID (X_i, Y_i)).
8: Assign distance D_i to each node for which ED (E_i, node_ID (X_i, Y_i)) < R.
9: If (W_i is same for all the sensing nodes) then
10: Choose minimum (D_i) as the sensing node (P).
11: $$R_t = (cost * ED(i,j))^2$$.
12: End if.
13: If ($W_t$ has different values at any instant) then
14: If ($D_1 < D_2$ and $W_1 < W_2$) then
15: Add delay (go to step 12 and calculate response time for $W_2$).
16: End if.
17: End if.
18: End procedure.

5. RESULTS
For analysis, a set of ten events are taken randomly, calculating their Euclidean distance from the set of nodes deployed. As soon as a sensor node senses an event, it sends its response to its parent on the basis of weight path value. The implementation work is carried out using stand-alone CPP packages and the results of WP approach are compared with WQRT approach by plotting the response time of each node for both the balanced and unbalanced workloads.

As shown in Fig. 2, 3 and 4 below, the response times of WP and WQRT are compared. The response time for balanced workload is lesser as compared to the unbalanced workload. It was seen that in case of WQRT, same node senses and sends the event response multiple times due to which with increase in the number of nodes, the energy depletion will be faster. In WP approach, the fare share of energy is possible among the sensor nodes, due to which the coverage, lifetime of the sensor node, and in turn, the lifetime of the whole network is enhanced with effective response time.

6. CONCLUSION
Since an energy constrained event driven WSN requires a fast response for anomaly detection, the delay in query forwarding becomes critical. Moreover lesser energy consumption leads to a longer lifetime which is eventually the main aim of coverage. It is observed that by using a rating method in terms of weight ensures a tree based architecture to be able to balance the energy depletion better as well as proves to achieve a better response time. This work is preliminary and needs to be extended for a larger set of nodes.

REFERENCES


AUTHOR PROFILES

1. Itu Snigdh received the Masters degree in software engineering from BIT Mesra (Ranchi). Currently, she is an Associate Professor in the department of Computer Science and Engineering at BIT Mesra and also pursuing her Ph.D. from the same institute. She has a couple of national and international publications in the field of Wireless Sensor Networks and network security. Her areas of interest include Software Engineering, Database Management Systems and Wireless Sensor Networks.

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