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A Generic Framework for Environment Monitoring System Based on Location Aware Sensor Networks

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Abstract

In this paper, the authors propose a model for a Generic Environment Management System based on Location Aware Distributed Sensor Networks. Information prioritization, buffering and optimal path discovery for routing of information packets are essential to the model to achieve maximum life-time. Clustering and layering of sensor nodes provides a low energy consuming method for routing and the model proposes a scheduling algorithm for multiple data arriving at head node of a cluster. To prioritize the information a representation scheme for natural phenomenon is discussed which takes into account the phenomenon type and impact value. The scheme uses impact values to prioritize the information arriving at head nodes.

The authors also propose a system based on hierarchical transmission of packets from sensor nodes to the base station by identifying a path from one head to a subsequent head along the route. The algorithm divides the entire sensor network into logical concentric layers based on energy of transmission whereby the packet is transmitted from a head-node to one of the head-nodes in the next layer with lesser depth. This is done on the basis of local angular deviation between two communicating heads, with preference for least deviant node. This leads to local route discovery and alternative path information maintenance, with the locations of only those heads in the subsequent layer to which the packet can be communicated (within transmission-energy constraints), recorded and maintained.

Keywords: Clustering, Layer, Selection, Prioritization**.**

1 Introduction

The surveillance technology has seen considerable advancements with the development of distributed wireless sensor networks [6]. The monitoring of remote inhabitable areas is made possible using this technology. An important issue here is conserving battery energy of sensor nodes because recharging is an impossible task.

The primary energy consuming activities of a sensor network are Route discovery, Packet transmission, Packet reception, Idle listening and Local Computation [10]. Out of these activities, route discovery and idle listening are the costliest. Idle listening can be eliminated by keeping the sensors in standby mode unless there is some activity. Route discovery is a major concern again as conventional algorithms depend largely on flooding.

Therefore, for this framework, location awareness of sensor nodes is essential means to optimize the route discovery procedure as well as local computations.

This framework cannot be applied to extremely ad-hoc networks, such as military surveillance of enemy territory, in its current state. This is because the whole implementation is heavily dependent on the localized co-ordinate system.

The implementation can be extended to mobile and ad-hoc networks with GPS enabling of the nodes.

This framework uses the same network infrastructure for monitoring various physical phenomena reducing the cost of deployment of wireless sensor networks.

2 Distribution of multiple types of Sensors

The framework supports monitoring of multiple environmental phenomena. Thus, various kinds of sensor nodes can be present in the network, ex pressure sensors, temperature sensors, heat sensors etc each measuring different phenomena.

2.1 Information Representation

This section describes the information that is sent by the sensors to the cluster head. The information consists of

1) Phenomena Type**:** An integer corresponding to a phenomena type. These values are predefined for various phenomena
2) Sensor Value**:** The value sensed by the sensor.

3) Impact Value**:** This value determines the priority of information sent. This is set by the sensor. An alarming phenomenon will have a high impact value whereas an ordinary phenomenon will have a lower impact value.

Table 1 shows a sample information representation scheme.

Phenomenon Name	**Phenomena Type**	**Sensor value**	**Impact value**
Wind Velocity	4	15	6
Temperature	3	25	5
Pressure	2	76	4
Humidity	1	10	1

Table 1

3 Deployment of Sensor Network

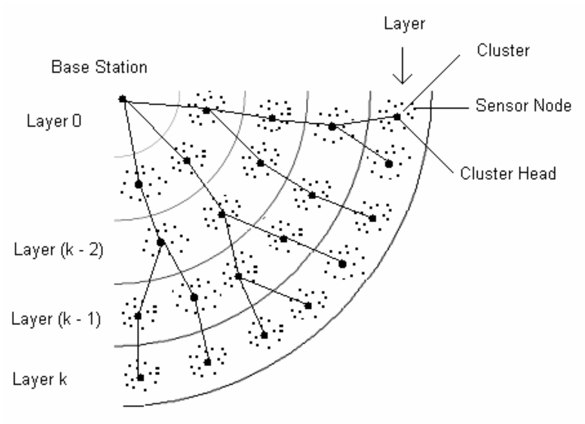

Figure1. Hierarchical distribution of sensor nodes in Distributed Sensor Networks

A clustered layer based approach is being used here. Sensor nodes form a cluster and the heads of clusters are distributed in layers.

Clustering is an energy efficient way for routing in sensor networks[1],[10],[4]. Each sensor node transmits packets to its cluster head (primary head) in a single hop. It is then the responsibility of the head to transmit it further.

The region is divided into layers based on transmission energy of heads. A head in the k^{th} layer transmits packets to the closest head in the $(k-1)^{th}$ layer in a single hop. The receiving head then transmits to the closest head in $(k-2)^{th}$ layer and so on until the packets reach the Base Station which is in Layer 0 (Figure 1). Thus, the transmission is a layer based multi hop approach. Here we assume that the distribution of sensors is such that each head has at least one head in the immediate lower layer to which the packets can be transmitted.

Each sensor node owns primary membership with its cluster head. If a head fails then other sensor nodes of that cluster participate in the election of new head node.

4 Prioritzation and Scheduling

Head node receives multiple data from cluster nodes. The information received has different urgencies and thus needs to be prioritized. 'Impact Value' is used to decide the priority. The higher the impact value the higher the priority.

Information is stored in a buffer at the head node. The information having higher priority comes first in the buffer. The buffer data structure is a priority queue.

Let the buffer size be N and there be M entries in it. If the buffer is full, all the information is sent to the base station. If $M < N$ then buffer waits to fill in the rest $N – M$ entries.

Now, let there be k information arriving at the head. If $k <= N – M$ then priority queue is formed of the k information and merged with the buffer priority queue. If $k > N – M$ then only the top most priority $N – M$ information is merged with the buffer priority queue. The algorithm is stated below

Algorithm 1

```
Algorithm Add_to_Buffer()
{
    While (M != N)
    {
        If (k <= N – M) {
// Forms a priority queue of k incoming information
            form_queue_cominginfo();
//Merge buffer priority queue with the previously
//formed priority queue
            merge_buffer_cominginfo();
            M = M + k;
        }
        else {
// Form priority queue of N – M most priority
information
            form_queue_topcominginfo();
//Merge buffer priority queue with the previously
formed priority queue.
            merge_buffer_topcominginfo();
```

```
            M = N;
        }
    }
//Buffer is full, thus send all the information to base station
Send_packet();
M = 0;
}
```

5 Route Discovery Algorithm

Sensor nodes form a cluster and the heads of clusters are distributed in layers. Clustering considerably reduces the hop count [1],[4],[10]. Each sensor node transmits packets to its cluster head (primary head) in a single hop. Each head transmits the packets to the nearest head in immediate lower layer.

The energy expenditure in sending information from one head to another head is quite large as compared to energy expenditure in sending information from sensor to cluster head.

Conventional routing algorithms mostly form a spanning tree, which gives all possible routes along its edges. Since most of these routes don't lead to the base station, it becomes a costly method [9],[11].

On the contrary, the method suggested here heavily uses Location Awareness of sensor nodes to construct a better routing algorithm minimizing energy consumption.

At the time of installation, each head node is fed with its layer no. and angular deviation from positive X axis. Each head node maintains a routing table as follows.

Node ID	Layer No	Angular Deviation	Flag

Table 2

Node ID is the address of head node, Layer number represents the logical layer and Angular Deviation measures the difference of the angle between a given node and its neighbouring node. For example, if θ and θ_i are the angles of the given and neighbouring node respectively from the positive X axis then angular deviation for the neighbour is $| \theta - \theta_i |$. Flag indicates whether the neighbouring node is alive or dead.

After the network boots each node keeps broadcasting Route Discovery Message at regular intervals. It also receives Route Discovery Messages from other nodes. If a message comes from head of immediate lower layer, the table is updated with this information. Then the node with minimum deviation is selected as the parent node for routing.

This algorithm transmits the packets in the most possible radial path, hence minimizing the distance covered by packet reducing energy consumption. Since the packets are transmitted from one layer to the other in a single hop and not to upper layer there is no cycle formation as in traditional algorithms.

Algorithm 2

```
Algorithm Make_Routing_Table()
{
    While (1) {
      // Broadcast route discovery message at
      //regular interval
    Broadcast_Route_Discovery_Msg (self node id, layer, theta);
    //Process only those route discovery message
    //received from immediate lower layer
    Receive_Route_Discovery_Msg();
    Update_Table(Nodeid, LayerNo, Theta);
    Select_Next_Route();
}

Update_Table( NodeId, LayerNo, Theta)
{
    If (node is already present and valid.)
        Do nothing ;
    Else {
        If (Table is not full) {
            AddEntry();
        }
      Else {
      // Node with the maximum angular deviation
      //will be replaced
            FindEntryToBeReplaced();
            AddEntry();
        }
    }
Select_Next_Route()
{
  Node next_parent = NULL;
  next_parent=find_minimum_deviation_node()
  return next_parent();
}
```

Algorithm 2 uses a greedy method in selection of parent node among the head nodes of next layer for route discovery. The storage space is also less than that in conventional algorithms.

6 Simulation

Simulation of routing algorithm described in this application has been done in TOSSIM on a workstation with 1.80 GHz CPU and 512 MB RAM. TinyViz is used for graphical visualization and for collection of data for energy consumption.

We considered 108 head nodes in total distributed among the 9 layers. The number of nodes in a layer increases with the layer number.

In this simulation we have used the following linear function for node distribution.

$$N = \begin{cases} 1 & \text{for } L = 0 \\ 2*(L+1) & \text{otherwise} \end{cases}$$

Where N is the number of nodes in a layer for Layer Number L.

These 2*(L + 1) nodes are distributed in L^{th} layer radially and randomly but with almost uniform angular deviations. This is done to provide better connectivity to each node with its neighbours.

The sensor data received at head node from its cluster nodes is generated using a random function.

Simulation was run from layer1 to layer 9 for 20 virtual seconds in each run.

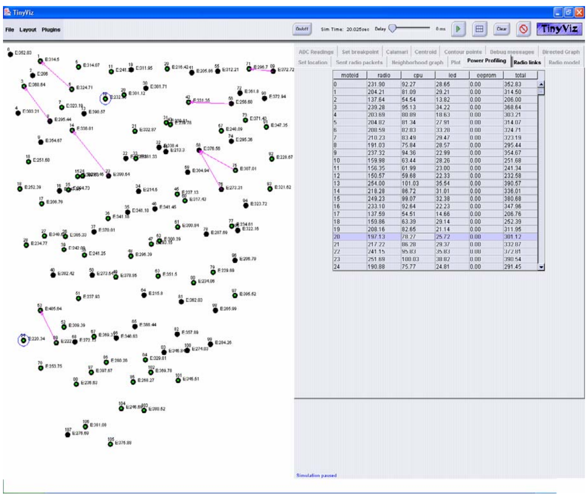

Figure2. Simulation of the application

Figure 3 shows the variation of the total energy with respect to no. of head nodes deployed in the network.

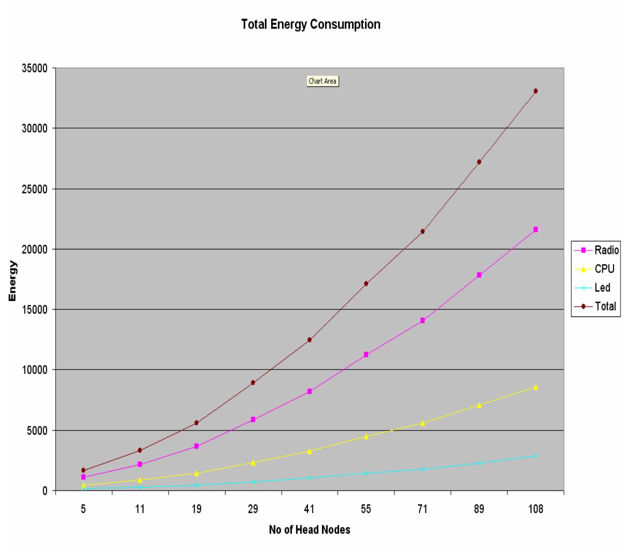

Figure 3

As we can see the energy consumption is almost linear with the increase in number of head nodes.

Figure 4 shows the average energy consumption in various components of sensor nodes.

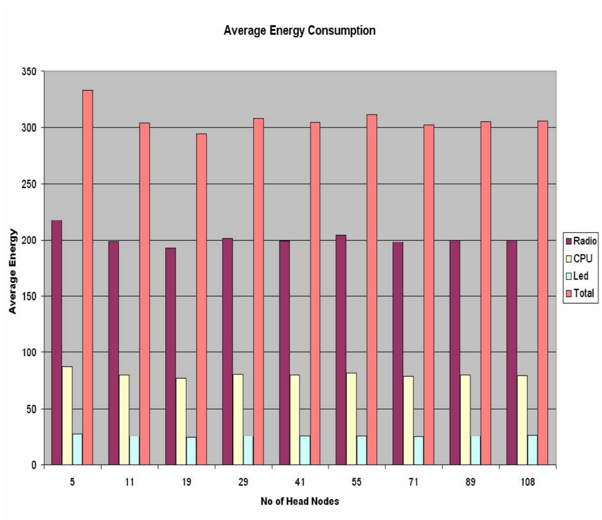

Figure 4

Average energy consumption is almost same in all simulation run. Thus it can be inferred that power consumption is distributed equally among all head nodes.

7 Conclusion

The life time of sensor network can be prolonged by minimizing energy consumption in routing.

Priority scheduling and buffering mechanisms can provide cost effective methodologies for transmission and hence enhancing head life time

The location awareness of sensors combined with the algorithms proposed provides energy saving route discovery and transmission mechanisms.

Overall, these measures can provide means to prolong the life time of distributed sensor networks by optimizing energy consumption in two of the costliest activities of a sensor network, viz. route discovery and transmission.

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