Efficient path discovery for transmission of data in agricultural field using wireless sensor networks

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***Abstract*— Data to be delivered to the base station from the source to the sink should consume minimum amount of energy. This helps to enhance the life time of the network. In this paper we are finding the best possible path to transmit data from the source to the base station using the specifications as used in agriculture.**

Keywords*— *Wireless sensor network , data transmission, agriculture

I. Introduction

Sensors are responsible for capturing, analyzing and transmitting information using radio signals. Sensor networks contain a base station usually called a sink and enormous number of other sensors which carry out the task of sensing and transmitting, along with relaying information of other nodes. Sink is a high computation device used to gather information of the whole network and is normally connected to the Internet or other data processing equipment. Sensors are highly resource constrained, major being battery power, transmission range, data and program memory. Sensors are application specific and can be used to continuously sample physical data like humidity, temperature, soil moisture etc. They are statically or dynamically deployed based on the application and are either battery, solar or power grid driven.

Sensors are self-organizing, detecting their neighbors, communicating with each other and exchanging information. All these concepts are used and applied in the agricultural application in this paper.

Scarcity of water is a major issue faced by the world. An awareness of water consumption is very much essential to avoid depletion of water in the water bed. Knowledge of water usage if provided to a farmer could help them in significantly improving the way water is managed [1]. Sensors placed in the soil could help in detecting the soil moisture; and this data collected by the network could help in regulating the water flow to the fields [2]. Analysis of data collected could help in predicting the yield and any new strategies can be adopted to overcome any associated problems.

II. Related Work

Sensors play an important role when it comes to sensing environment parameters like water pressure, humidity and temperature in the agricultural field. COMMON-Sense is one such project associated with monitoring the regulation of water supply to the field [3]. The sensors used here are placed at a depth of 15cm to 30cm and the moisture content is sensed. Based on this project the path finding algorithm has be framed using network simulator ns2.34.

III. Routing Algorithm

A. Routing Table

Routing tables are maintained with every node maintaining all the associated information. In the current algorithm the table has the following information. The current nodes address (id), the previous node id (node from where it can receive information), the next node id (where it should transfer the information), hop count (the number of hops required to reach the destination), neighbors list (containing the id of all the neighbors). Fig. 1 shows the routing table information stored in each of the nodes.

Information stored	Size occupied
Node id	4 bytes
Previous node	4 bytes
Next hop node	4 bytes
Source node address	4 bytes
Destination node address	4 bytes
Neighbors list address	4 bytes
Time stamp	4 bytes
Sequence number	1 byte
Hop Count	1 byte

B. Packets

Various types of packets are used for path finding, path establishment and data transmission. The current path finding algorithm is based on the AOV protocol [4]. Following are the various types of packets used during the various phases of transmission.

1) Packets for broadcasting from the source to sink during path finding process: To find the route from the source (sensing nodes) to sink (base station) we need packets to be sent across the network. Packets used here contain the following information, the source and destination node address (sink) along with the hop count, packet type, sequence number and the timestamp when the packet are sent. Fig. 2 shows the packet format which is used for broadcasting.

```
0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Packet type    |Sequence Number|Hop Count      |    Reserved
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Destination node  Address
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Source node Address
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Time stamp
-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2. Broadcast packet

2) Packets for unicasting from the sink to source during path establishement: Packets sent from sink carry with it the basestation or sink id (source node address) and the source id (destination node address) and time of sending the packet along with packet type. Fig. 3 shows the packet format which is used to find the return path.

```
0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Packet type    |    Reserved
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Destination node   Address
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Source node Address
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                              Time stamp
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3. Return path packet

3) Data packets during data transmission: These packets contain the data information along with the destination and source address along with packet type, sequence number and hopcount. Fig. 4 shows the data packet format.

```
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Packet pe      |Sequence Number|Hop Count      |    Reserved
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Destination node   Address
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Source node Address
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Time stamp
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4. The data packet

C. Path finding

Initially the source node has no information of the previous or the next node. The only information available is the source node address and the destination address. Hence the source has to broadcast the message to all the neighbors. Fig. 5 shows how the packet is broadcast to all the neighbors.

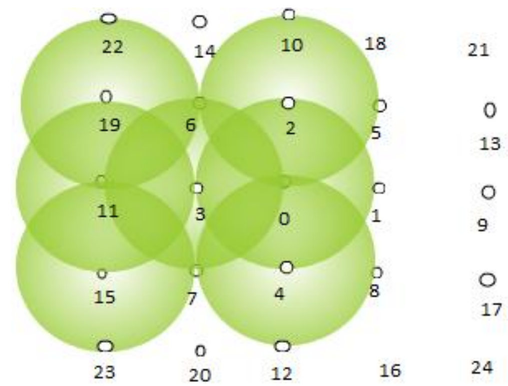

Figure 5. Broadcasting of packets

These neighbors will in turn broadcast the message to all its neighbors until it reaches the destination. All the neighbors in the hearing range will accept the packet and get their routing tables updated. The neighbors will update their previous node information along with hop count from the source and its neighbors list. This process of broadcasting and updating will carry on till it reaches the base station. Fig. 6 shows how the packets are broadcast from the source node to the base station (sink). Node 23 is the source and node 0 the base station. The topology is so selected that, in the grid structure at the maximum of four nodes are the neighbors of the node [5]. For longer life of the network we have hexagonal topology as shown in Fig. 9. In hexagonal topology maximum of only three nodes are in the hearing range of each other. This avoids unnecessary transmission and wastage of energy.

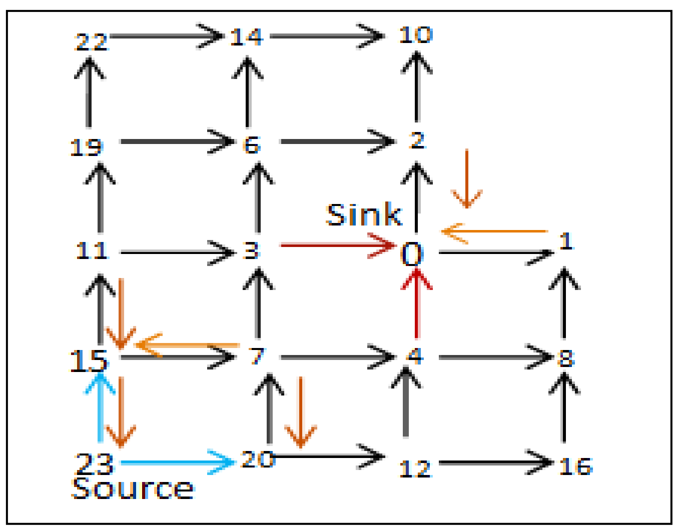

Figure 6. The grid topology

Packets transmitted from node 23 is received by its neighbors 20 and 15 which in turn is send to its corresponding neighbors 11,7,23 and 23,7,12. The packets which are sent from node 23 can be received back by 23 when it is retransmitted by the nodes 20 and 15. These packets are being freed by the source node 23as it received the same packets that it had sent (loop formation). This is because the source node address and the node which received this packet are having the same address.

The node 7 receives two packets, one transmitted from node 20 and one from 15. The routing table of node 7 is updated based on which node sent the packet to it first. The previous node for this node is the one who sent the packet to it first, but it maintains in the neighbors list both the nodes 20 and 15 as its neighbors. The packets which came late and are having the same hop count are freed as it transmitted with a delay (multi path traversal with same hop count). As is seen from the Fig.6 we could get packets from 2, 3, 1 or 4 to the base station (node id 0). But the first packet with a hop count of 4 (minimum hop count here) is the one which is updated as the previous node in the routing table for 0.

The sequence of packets received by 3 could be from 23→15→11→19→6→3 with 5 hop counts. This would update the routing table at 3 with its neighbor being 6 and 5 hop count to reach 3 from the source and previous node information with 6. But at a later time there could be a packet from 23→15→7→3 with a hop count of 3. This results in the updation of the routing table with previous node as 7 and hop count of 3. 7 is also added as the neighbor of 3. This process is repeated for all nodes which receive new packet with lower hop count (multipath with lower hop count).

The nodes could get the packets from the neighbors with higher hop count. The neighbor information is added to neighbors list, but the packets are freed (multipath with higher hop count).

The time when first packet is received by the sink is first noted. The time of sending the packet from the source is also noted. The time to traverse from the source to the sink is calculated which is the difference between the two interval. The waiting time to accept all the packets is kept to twice the time required for the first packet to reach the sink. All the above processing is done for this interval. After this period all packets are freed. Along the path all the nodes have updated their previous node id from where they have received the packets. This previous node information now helps in establishing a path back from the sink to the source.

D. Path Establishment

To establish a path from the sink to source we now use unicast transmission and send the packets from the sink to the source looking at the previous node information updated during path finding process. Fig. 7 shows one of the many available paths from sink node 0 to source 23. During this process the next hop field is entered in the routing table. This information has to be updated by every node (i.e. from where this packet is received). Hence a path from 0 to 23 is established with 4 hop counts either from node 3 or node 4. When either of these nodes receives the packet their next hop field is updated as 0.

E. Data Transmission

These packets contain the data which has to be transmitted to the sink. Fig. 8 shows the reverse path established to transmit the data.

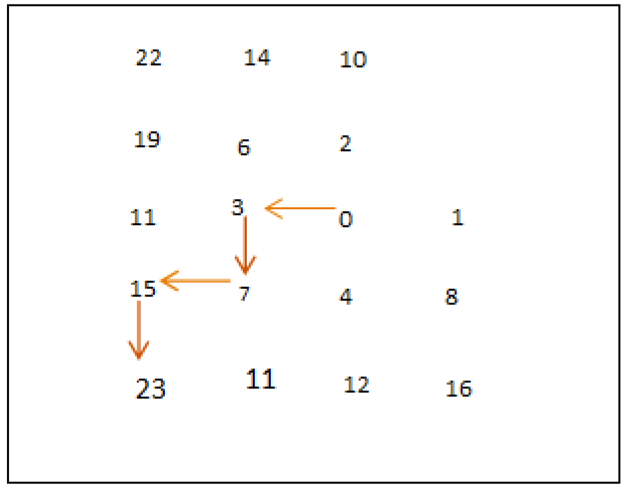

Figure 7. Reverse path established to transmit the data

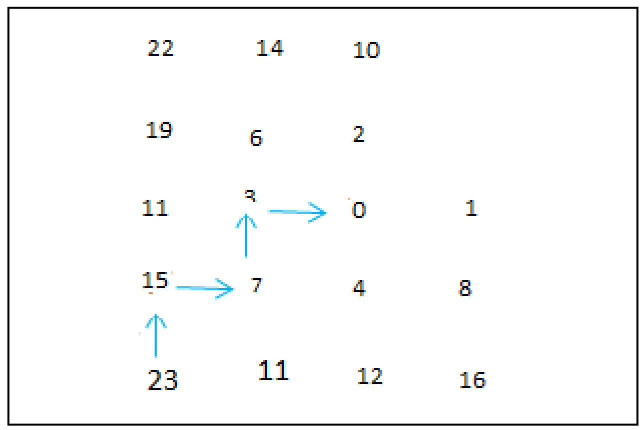

Figure 8. Path to transmit the data

F. Data Interval

The data that is collected is once in every 5 minutes during monsoon when it rains heavily and once a day during dry days. Hence readings are obtained once in every 300s.

IV. SIMULATION

The simulation is carried out using ns2.34. The parameter initialization is based on the environment necessary for the agricultural purposes [6]. Specifications correspond to the mote Tinynode. We have the receive threshold -104dBm (3.98e-014) for 5dBm (3.2mW) transmit power. The Carrier sense threshold is -104dBm. Capture threshold of 10dBm. Frequency of operation as supported by Tinynode is 868MHz and 915MHz. We have chosen 915MHz. Two ray propagation model with antenna height of transmitter and receiver as 1m.

Distance between the nodes as supported with these values is 532m.

The sensor node specifications are as follows. Two alkaline batteries of 1.5V each are used. The voltage requirement is 3V for the operation of the sensors. The transmit power is 0.999W for a current of 33mA. The receive power is 0.042W for a current of 14mA and the idle power is 3μW for a current of 1μA.

The power consumption of the alkaline battery is 0.705W and the energy available for 80 hours of operation of the battery is 20304Ws. The simulation period is kept for 288000secs. The data is transmitted at the rate of once every 5 minutes.

The topology involves an area of 13300*13300 m. The number of nodes used is 448. Traffic type is Constant Bit Rate at 76.8Kbps. The base station is placed at the center of the field with node number 216 and the source is node 0 as depicted in the Fig. 9.

The simulation was carried out successfully for the stipulated period. Around 2000mW of power was consumed by the sensor nodes. Large amount of power consumption is during the idle period.

Figure 9. Topology on which the algorithm was executed.

CONCLUSIONS

Efficient path, consuming less energy is essential for longer run of sensor networks. In order to achieve this, the nodes are placed in hexagonal order reducing the number of neighbors, which in turn reduces unnecessary transmission of packet and saves energy. Various types of packets are used for finding the route, and later transmission of data. The topology though could run successfully for the stipulated period, it can be made to run for many more hours by putting the nodes to sleep when it is idle and waking them up only when it required possibly once in every 5 minutes. This could enhance the network life considerably.

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