PRECISION CROP MANAGEMENT BASED ON WIRELESS MESH NETWORK IN AGRICULTURE

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Abstract - All the enhancements in wireless personal area network made it possible to implement various services into action. Earlier it was considered costly and labor intensive. A wireless sensor network is built, in which the climatological properties like moisture content, temperature and the other environmental properties are sensed and relayed to a central repository. The architecture consists of three major aspects like soil pH, soil temperature, electrical conductivity and soil moisture, which are suited or the most common crops, are considered and sensor is selected based on those aspects.
The sensor network is based on IEEE 802.15.4 standard. A new static routing algorithm is developed which overrides the pitfalls of the C_{skip} addressing algorithm in Zigbee technology. This routing algorithm maintains hierarchial network topology and ensures optimal routing. Actuation components are utilized to control irrigation and fertilization. These actuation components are a part of the mesh network and are activated wirelessly.

Keywords: Sensor networks, Actuation, Routing, RFID.

1 INTRODUCTION

Agricultural production has to meet the nutritional demand of the world population. Agricultural production also has to ooperate within strict economic boundaries and has to minimize environmental impact. One approach to maintain a high fieldproductivity and increased nutrient efficiency is Precision Agriculture. Precision Agriculture is defined as 'the application of technologies to manage the major requirements of the crop for the purpose of improving crop performance, profitability and environmental quality'. Precision Agriculture ensures better quality control and increased yield at a lower cost. Precision Agriculture may make use of completely automated machinery. Since Precision Agriculture utilizes automated machinery, Precision Agriculture requires devices with high capability of sensing the climatic conditions and broadcasting the sensed data to the central station. The central station, based on the sensed data, makes decisions and controls the farm equipments. The sensing technology allows us to identify the presence of pets, nutrients in the crops, drought, misture content, etc. Once when the data are received, the central station controls the irrigation and fertigaton through the automated actuation devices like valve-controlled irrigation system, sprinklers, etc. The Precision Agriculture has the following major stages (i) sensing agricultural parameters (ii) transmission of sensed data to central station (iii) decisions made based on sensed data. Once when data are received, the central station controls the irrigation and fertigation through the automated actuation devices like valve-controlled irrigation system, sprinklers, etc. which are already available.

2 RELATED WORK

Precison Agriculture is being discussed for past few years. Earlier Precision Agriculture was considered unprofitable because of the high initial investment for the electronic devices. This lead to a situation that only large farms were able to afford it. In this stage, the technology coonsisted the following three aspects (a) Remote Sensing (RS), (b) Geosynchronous Positioning System (GPS) and (c) Geographical Information System (GIS). The characteristics of the soil are tealized by generation of maps of the soil. The maps are generated by RS coupled with GPS coordinates. The electronic sensors and remote optical scanners from satellites will sense the properties from the samplings. The collection of such data leads to the GIS. The data are analysed statistically and the variability of the lands based on their properties was charted. But previously, it was considered an expensive technology and labor-intensive. Over the last few years, all the advancements in the wireless technologies lead to loow power requirements, decreased cost of deployment and decreased cost in running a feasible Precision Agriculture framework. Due to these developments in the technology, sensing and communication can be done with better response times. The wireless sensors are utilized in Precision Agriculture for their cheaper rate and robust communication. Wireless sensor networks allow faster deployment and installation of various types of sensors. These networks provide self-organizing, self-diagonising and self-healing capabilities to the sensor nodes.

2.1 Smart Field System:

The presence of plant viruses and the level of soil nutrients are the conditions that a farmer may want to scrutinize. These viruses or nutrients operate at nano-scale. So sensors which are capable of running at nano-scale level are required for deployment of

'Smart Field'. The US Department of Agriculture (USDA) is involved in a progressive work of developing a 'Smart Field System' that analyse, locate, report, supply water, fertilizers or pesticides automatically.

2.2 Soil Net:

Soil moisture plays a vital role in the growth of the plants. Land covers, soil conditons and topography act to redistribute soil moisture. In this project, soil moisture sensor network is developed to monitor the soil water content changes at high spatial and temporal scale. Key features of Soil Net are as follows

- A Wirless Sensor Network with Mesh topology based on Zigbee.
- Long battery life due to low energy consumption.
- Extendable network.
- Reactive to external influences.
- Use of database for the storage of collected data.
- Easy and variable access of database.

In real time, the small catchment area of the Wustebach of about 26.7 ha is used for the deployment of the proposed soil moisture network Soil Net. This network consists of 286 subnodes and 12 coordinator nodes. The whole network was considered to be managed by a main server which enables online transmission.

3 PROPOSED TEST-BED FRAMEWORK

Controlling the irrigation and fertigation automatically based on certain conditions leads to Precision Agriculture. So, in this paper we have designed a Wireless Sensor Network test bed for remote monitoring the agricultural parameters. This Wireless Sensor Network is achieved using IEEE 802.15.4 based LR WPAN technology. The proposed architecture can be classified into three areas:

- Sensing the parameters of agriculture
- Addressing sensors and routers
- Decisions in actuating and controlling based on sensed data

3.1 Description of the system

The required attributes of the soil or atmosphere are captured through the sensors which placed at different locations in the field.

The output of the sensor will be in the analog form. Now the output is fed into a microprocessor based RF unit like the Chipcon CC2420. The data will now be in the digital form which is then packetised and dispatched to the central repository. The path taken by the data through the routers is optimised by a new static algorithm. An apriori association of sensors and its address can be made. This is because the sensors with RF module s are static and each of them has an unique identity. The architecture is pictorially shown in the figure. All the RF devices can be considered as RFID nodes. Every such node and every sensor has its own identity and its location. The RFID nodes are to perform three vital roles given below.

- Active RFID Gateway
- Active RFID Tags with sensors
- Active RFID Routers

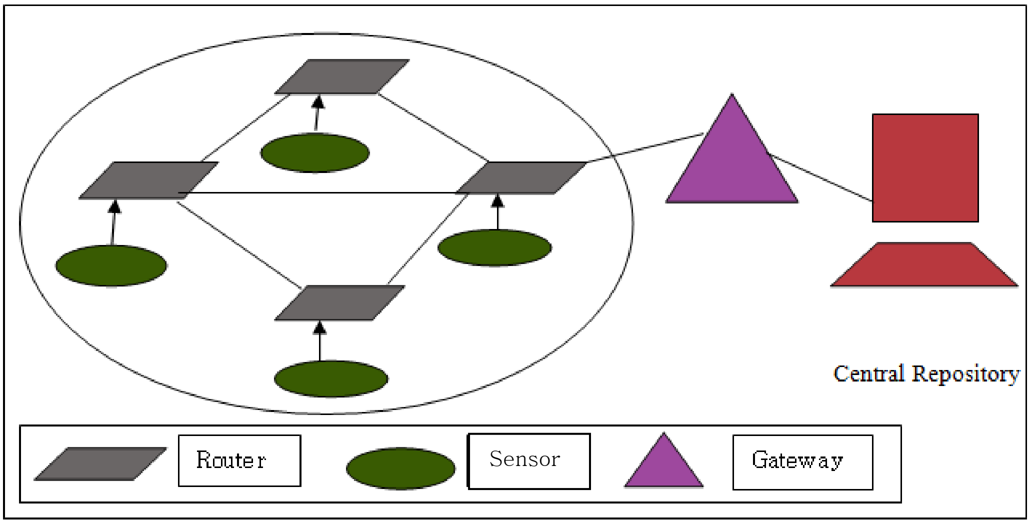


Figure1. Architecture of Wireless Sensor Network

3.1.1 Active RFID Gateway:

Active RFID Gateway is a master controller that coordinates the mesh network, collects the sensor data and transfer it to the central system. The collected data might also be broadcasted over a GSM/CDMA mobile connection.

3.1.2 Active RFID Tags with Sensors:

To sense the attributes of the crop field we use active RFID Tags connected with sensors which is known to be a sensing device.

This tag can also be used to regulate the actuators as per the control decisions.

3.1.3 Active RFID Routers:

Active RFID Routers can be utilised for the range extension of the other active RFID devices. Routers are placed in a static location forming a IEEE 802.15.4 wireless mesh network. The location of the tags are determined based in the location of the routers.

3.2 Sensing agricultural parameters

Precision Agriculture is primarily based on the type of the crop. Here, we have identified four parameters which are critical for most of the crops. The parameters are

- Soil pH
- Soil moisture
- Electrical conductivity
- Soil temperature

3.3 Addressing of Sensors and Routing

The most common choice of the mesh network would be the Zigbee standard. But the CSkip algorithm used in the Zigbee was found to be lacking due to the need of a large network. In this section, we state the need for tree based network and highlight its properties. Then the deficiencies of the CSkip addressing algorithm will be elicitated. Thus a new static addressing algorithm is proposed where routing will be efficient.

3.3.1 Tree based network topology

The Zigbee standard is based on the PHY and MAC layers of IEEE 802.15.4. This standard provides specifications for two kinds of network topologies - mesh an tree. Mesh networks utilize the slightly modified ad-hoc on-demand distance vector (AODV). However hierarchial scheme is preferred over the mesh networks in the realm of sensing and tracking applications. The characteristics of such applications are

The deployment area is identified where the path is to be sensed and the routers which are also known as Full Functional Devices (FFDs) are placed along this path. The flow of data will always be between the coordinator and the end device and vice-versa. There is never a need for end devices to talk to each other. The location of the routers can be optimized by design which ensures low cost of hardware. The knowledge of the topology provides the fault tolerance capability and establishes the bounds on latency. Bounds on network lifetime can also be studied. Such bounds cannot be obtained from mesh topology. So tree topology is favored in this concept.

3.3.2 Disadvantages of C_{skip} Algorithm

Routing based on tree structure has been shown to be the most efficient and thus the formation of the network topology is done based on a tree. Zigbee uses CSkip algorithm for allocation of address and building the network. In CSkip algorithm, a short address is to be given to the new devices requesting for an association. The allocation of addresses will follow the rules of the network parameters which are predetermined and static. The parameters are Cm, Rm and Lm; where Cm=maximum number of children that a full funtional device can have; Rm=maximum number of children (out of Cm) which are FFDs; and Lm= maximum depthof the network. The values of these parameters are stored in NIB (Network Information Base) in each device. The child requesting is given a device generated by the equation:

$$A_n = A_{parent} + C_{Skip}(d)*R_n + n$$

where A_n is the address given to the new device. A_{parent} is the address of the parent of the device that assigns tne address. $C_{skip}(d)$ is determined as follows:

$$C_{skip}(d) = \frac{(1 + C_m - R_m - C_m * R_m^{(Cm - d - 1)})}{(1 - R_m)}$$

$C_{skip}(d)$ determines the block of addresses which the parent device must skip before assigning the next address. This algorithm considers the worst case scenario and provides accomodation for all the devices of the predetermined network architecture. This worst case assumption will severely affect the depth of the network. The addressing scheme based on Cskip develops a tree topology. This makes optimal routing possible. Routing is done by comparinb the destination address with the Cskip allocation block. If the Cskip block contains the destination address within its block of the its child, then the data packet is forwarded to that chil else it is sent to its parent. For example consider Cm= 6, Rm= 6 and Lm= 7 for a 16 bit short address. It has been shown that a minimum latency is provided by the tree topology. The address wastage problem is shown below.

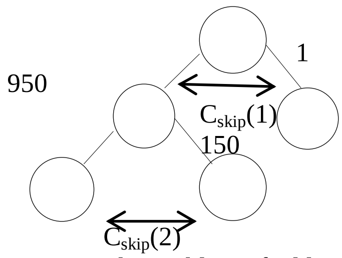


Figure2. The problem of address wastage

3.3.2 Proposed Static Addressing algorithm

To prevent the address wastage and maintain optimal routing through tree structure, a new routing algorithm is developed. First, a pictorial topology of the locations of the routers is prepared. The maximum number of devices that a router would have to handle is estimated (En). Then, by a simple algorithm the address of each router is determined. The algorithm follows the depth first concept and thus the deepest node is assigned an address first. The needs of tracking allows us to set the address in advance to preserve the structure of the tree. The algorithm used is given below.

```
function main()
{
assign PAN_Coordinator_address = 0;
current_address = En + 1;
assign_address(PAN_Coordinator);
}
function assign_address(node)
{
for(all children of node from left to right)
assign_address(chil_node);
node_address = current_address;
for(all children of node)
{
parent_address(child_ node) = current_ address;
append into address list, child_node address;
}
 current_address += En + 1;
}
```

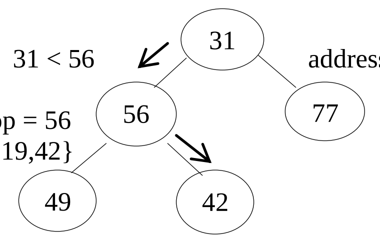
The addressing algorithm

Each router has the list of the addresses of its child routers and the routing is done based on this list. The address allocation is pictorially described in the figure 5.

Assume, a network topology as shown and En = 6. Here, the Cskip assumes the worst case and allocates address for the non-existing nodes. This leads to wastage of huge amount of address space which is overcome by the static algorithm. The sensing application has a well defined path which is known in advance. Thus, the need to preserve address for future nodes does not arise. The address allocation can suitably be tweaked to involve into a provision for an address for non existing future nodes as needed. This is achieved considering the larger value of En. The maximum address of all devices under a node is denoted by the node's address. Addresses to the end devices are assigned by the routers as node_address - n, where 1<= n <= En. The property of the node addresses is preserved at any point and thus routing is achieved. For example, consider an end device joins the network at node 35. An address of 31 is assigned to it. The routing decisions would be at each node and would check under which child the destination address must exist and forward the packets accordingly. The algorithm is given below.

```
address_list = {child router addresses};
if(dest _address =child _end _ device);
next _hop= dest_ address;
else
{
next _hop= parent_address;
for all address_list_entries
if(dest_address of packet <= address_list_entry)
{
next_hop = address_list_entry;
break;
}
loop
}
send_packet(next_hop);
```

The Routing algorithm



31 < 56 address_list = {56,77}

next_hop = 56

address _list = {19,42}

31 > 19

31 < 42

next_hop = 42

19

35

address_list = {31,28}

next_hop = 31

31

23

End device

Figure3. Packet routed from 0 to 31

3.4 Actuating and control decisions

The activity of actuation is dpne based on the input data supplied by the sensors. When the threshold value is exceede, then automated alerts are generated as messages on the console. Then actions are taken accordingly. Irrigation and fertigation systems can also be automated. Currently in drip irrigation and foggers, automated systems in avail. The controller end make use of special electrical switches to control these valve based actuators. The control decisions are considered to operate the actuators. A RFID device will be connected with each actuator to identify and control them uniquely.

4. CONCLUSION

In this paper, an architecture for Precision Agriculture based on wireless sensor networks is developed. The architecture consists of sensors, routers, gateway and actuators. The sensors are designed based on the crop field parameters like soil pH, electrical conductivity, soil moisture and soil tempearature. The mesh network is built in the hierarchial tree form. We refuse Zigbee standard and construct a network layer over the PHY andd MAC layers of IEEE 802.15.4. We explained about the newly developed static routing algorithm. Due to this new algorithm the need for mobility of sensors is decreaed. We can build the network quickly and with ease based on the apriori information. Therefore the address wastage problem in Cskip algorithm of Zigbee is avoided. The control and actuation is designed based on the hardware available in the market. The control decisions work on the parameters sensed through the rules set by the central station. Thus having hierarchial topology and new static algorithm, the efficiency of the routing is maintained.

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