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Robotic Based Wireless Sensor Network Architecture For Agricultural Applications

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Abstract-Wireless sensor technology has been proved useful in various applications requiring real time monitoring of the environment. In this paper we have used WSN technology along with a robotic platform and have proposed architecture for precision farming. This integration reduces the number of node required and hence the cost. The sensors used here are selected so that they will be suitable for movable nodes. Routing protocols and energy saving mechanisms also has been adapted to suit the changing location of the node. At the same there has been a provision for a backbone link for storage and processing of the data. The real world perception technology based robots and monitory sensors combination by reducing the complexity, budget, power requirements, isolation of the sensing and data processing and storing procedures give a new dimension to the application of WSN by adapting the WSN technology making it more suitable to rural, small scale implementations. Our proposal also focuses on the need of small and middle farmers. The technology will not only improve the yield of small/middle farmers but at the same time it can be helpful in reducing the excess of pesticides and insecticides.

KEYWORDS

Wireless sensor network, robotic sensor node, sink nodes, ad-hoc routing, agriculture

I. INTRODUCTION

Agriculture is the most important sector in terms of both economy and development. This sector either directly or indirectly has an important influence on our lives. Today this sector is facing extreme challenges like seasonal variations due to global warming, shortage of land, infertile soil, excess use of pesticides, excess irrigation etc. The worst circumstances are faced by the small farmers with small land holdings or family farms that depend only on family labour for agricultural work. The small land holder farmers and resource users continue to face difficulties in adaption and adoption of soil and water conservation techniques as well as do not have any access to any source of information for improved farming techniques. Out of 525 millions farms worldwide, about 90% are small holder farms (IAASTD, 2008). Small holder produces 80% of the developing world's food consumption. In this paper we have made an effort to exploit the combined advantages of wireless sensor technology, robotics and information and communication technology to develop an E-farming architecture which can helps in enhancing, précising the efficiencies of agricultural practices. Together with families of landless agriculture workers, smallholder farmers constitute of the world's hungry and poor. Viewing the percentage of small farmers it can be easily seen that by providing them facilities to improve their agricultural yield will directly benefit our economy. Thus we intend to design a system which on hand reduces the overall budget of a full fledged wireless sensor network installation and at the same time is easy to, self configuring requiring minimum technical assistance.

In this paper we have presented an architecture that integrates robotics and wireless sensor technology. This integration will sharply reduce the number of nodes required for real time monitoring of the farm providing the same level of performance as a densely employed sensor network would provide. The robotic platform should be based on principle of reactive navigation for its path determination. Also we have given a provision for a backbone link which will further provide the features of data recovery in case of failures, alerts when sensed data crosses the threshold, data logging to Bluetooth devices like mobile phones etc. Moreover a base station will also be installed at the farm site. The routing and energy saving procedures are modified to suit the architecture. The design of the sensor nodes will also require certain changes both at the hardware and software level to perform well being in mobility. Sensors are selected with the criteria that whether they can be mounted on a robotic platform giving accurate and precise information about plant health. Thus an overall architecture is proposed.

II. PROPOSED ARCHITECTURE

A. Robotic Platform

Earlier robotic technology was vehicle and application centric but now due to emergence of high performance micro computers, advanced sensor based systems robots are adapted to situational awareness, outdoor vision, mapping and localization, dynamics and control, shared autonomy and robot sensor network interaction. A new era of automation through robotics is rising. Technologies like high speed scanning lasers, artificial intelligence are giving new meanings to the robotics. The robotic platform that we desire for our application is such that it should make its movement forward in its path on its own. Farms usually present a rough field with slopes, obstacles, trees, cables, pipelines etc. Thus the robot should be able to make its path on its own. The robot should be equipped with reactive navigation and opportunistic localization capabilities. We can use the Omni directional camera, accelerometer, laser scanners, GPS (Global Positioning Systems). Using these and various control and navigation algorithms the robot will have real-time based perception technologies. Many works are going around this. One such organization is the Common Wealth Scientific and Industrial Research Organization (CSIRO) which is the federal agency for scientific research in Australia. Among its many research flagship one is agriculture and it is conducting many researches in the field of autonomous sensing and robotics in agriculture. They are developing technologies to enable machines and devices to operate and survive in dynamic, unstructured and potentially hostile environment. The observations are translated into useful information in real time. One such project is the laser based pasture density measurement. Thus the automation, real world perception and navigational algorithms can be used to design an appropriate robotic platform for our application.

B. Sensors employed here are:-

- Electric noses or e-noses that mimic the human sense of smell using sensors that respond to airborne chemicals by producing an electronic signal. The distinctive smell of plants due to the cocktail of volatile organic compound (VOC). This smell changes when plants are under attack. It is this change of odour that an e-nose can detect. This helps in early detection of plant diseases.
- Reflectance based optical sensor-It is used to determine the health of the plant. Since plants absorb a specific wavelength light in the NIR spectrum. The absorption varies according to the health of the plant which can be detected by the sensor.
- Nitrous Oxide sensor-To detect the condition of water logging this sensor is used.
- Night activated acoustic sensor-This sensor will inform the farmer about any intrusion by wild animals. This will be provided with a GSM to message the farmer immediately about the intrusion and an alarm system to scare the animal.

Apart from the sensing modalities the sensor will contain a processor platform. The processor platform can be a low power microcontroller, a radio platform, analog to digital converter enabling interfacing of analog sensors. Also depending whether the node is a robotic one or static one their hardware will differ. The robotic node will require a GPS module. The sink node on the other hand can have data acquisition board like MDA300 attached to it, high storage capacity hardware and a Bluetooth module along with a radio platform. The power supply to the nodes can be either through battery or solar panel. If we use the battery power it will require frequent changes. In [1] with voltage requirement of 2.8V to 3.2V two battery changes were performed during their whole course.

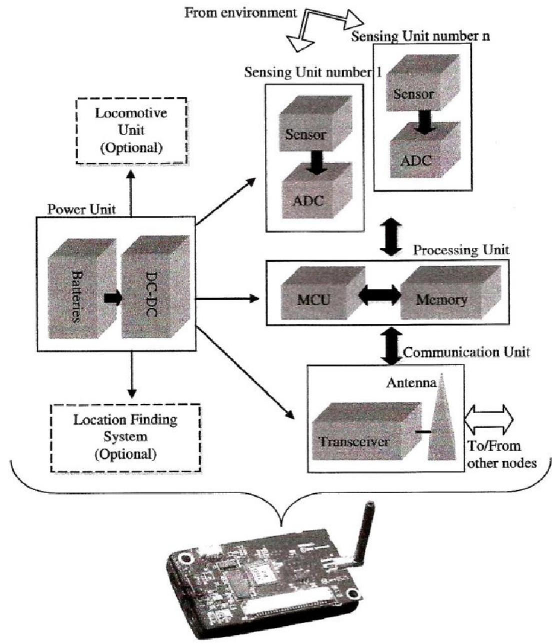

Fig. 1: shows the sensor node hardware.

C. Network Configurations

The deployment of the nodes in the farm depends on the farm size, the environment, terrain, foliage, trees as these may affect the routing of the information or the radio range connectivity. Considering a general range of 20-25m required between two nodes for radio connectivity. In case of static immobile nodes predeployment according to the area of interest is feasible but when using robotic nodes their position and hence their connectivity cannot be predetermined and will change during their course. Accordingly the architecture has to be designed for robust, efficient and power saving modes. Among the several options that we have, we chose ad-hoc routing for communication between the various nodes as this type of routing provides two benefits, automatically configuring the routing pattern of the data and being robust against the failure of individual nodes [1].

The architecture has two options either to opt for a two tier mechanism where few nodes will serve as only sensors and others as sensors and primary routers. In [1], [2], [3] this two tier approach is adopted and various routing protocols are given according to this approach like cluster, Pre-defined routing etc.

But in our architecture the mobility of the sensor nodes will be advantageous as all nodes will get a chance in its whole course for at least once to be within the radio coverage of the base station. And hence at that particular instant can transmit all its data to the base station. But this configuration puts some limitations like the data could be lost in case of node failure. Also the radio is reliable but imperfect so effort must be done to provide a backbone link. This backbone architecture will require inter node connectivity and

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employment of some sink nodes which will have fixed location. Now the data sensed by the robotic rode will be aggregated in these sink nodes. They will although introduce some redundancy but proper algorithms and protocols can be implemented in these nodes to organize the data in these nodes. These nodes will also be equipped with a Bluetooth module so that they can log the data when handheld Bluetooth activated devices like android based smart phones or simple mobile phones pass by. An application can also be built for the smart phones. This backbone will serve two purposes. Firstly it will overcome the real world limitations due to the environmental factors like temperature variation, dense foliage, cabling, and radio interference. Secondly an alternative display and monitoring unit using the android platform or some other Bluetooth enabled mobile phones. This networking gives the option of threshold sensitive alerts that is at the sink node thresholds are set and the sink node on receiving the sensed data will compare it with the thresholds and the crossing of the thresholds alerts will be immediately send to the farmers on their phones.

D. Node Deployment

Usually in sensor networks the nodes are located according to the radio connectivity [2] or in the areas of agricultural interests [2]. In this architecture first of all there is no as such an issue of deployment, due to the mobility of the nodes but a complexity arises when we talk about the area a node can cover whether an entire field or segments of a field. The answer lies in the robotics part based on how it is designed. If a single robot with enough battery power is used then it can traverse the entire field. But we can have some issues with these options. Firstly we will not be able to measure the real time data in the sense that the readings of various blocks of the field cannot be taken at the same instant and thus the intra-site variations cannot be observed. These intra-site variations are very important farming factors in the farming of vineyards [1] and other such crops. Moreover the performance will then not be comparable to the dense networks. Thus we will require more than one robotic node. But we still have the advantage of having much fewer sensing nodes than the usual sensor networks.

Taking one step further let us discuss the deployment of the nodes. Firstly the farm should be divided into columns of width 50m each. Each column will be allocated a robotic node. This node will traverse the column in a straight line path. If we compare this deployment with [2] where tubs were formed of size 13.2m and each tub contained three sensors we can really view a sharp reduce in the number of sensing nodes deployed by a factor of almost 66. So as in [2] a farm of 100x40m will roughly require 2 robotic nodes and one sink node. One thing to notify is that the number of sink nodes to be used should be decided on the basis of the dimensions of the field and the access to the robotic nodes and the base station. A cluster based hierarchical network for the sink nodes will prove suitable. The cluster head first sink node placed near the base station and further second layer sink nodes at a distance maintaining radio connectivity with the head node. Then further third layer nodes placed upwards within the radio connective range of the second layer and so on until farm is covered. Each layer except the first will have two sink nodes. The nodes at the edge will give Bluetooth connectivity. The nodes will be placed forming a slanted line on both sides of the head node. The sink nodes will be kept one column apart from their previous layer node. This deployment will enable each layer to communicate among them using multi hop routing and to share their data. But only the head node will interact with the base station that is receive sync signals from the base station which it will further transmit to other sink nodes. Also it is the head node which will transmit all the collected data from the sensor nodes to the base station on receiving request. Fig. 2 shows the basic node deployment scheme.

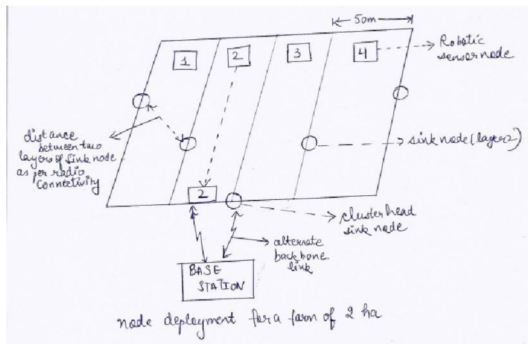

Fig. 2: node deployment for a 2 ha sized farm

GPS requirement

Identification of the node is important. In [2] it was done by assigning a tub id to each node and the cluster head. Here we will use the GPS which will be integrated with the robotic sensor node so that the data send by it will have a GPS slot in its TDMA frame (for each node). It will enable the application on mobile phone or the base station to plot the various data aggregates versus location. And we can have a pictorial view of the sensed data mapped in a map of the farm.

E. Node Software

The following OSI layer implementation is required at the node. The physical layer is implemented using the radio frequency module in the robotic node and by bluetooth /radio frequency module at the sink node. The second layer will be the MAC layer. The various mechanisms like the duty cycling for power saving, broadcasting of a message, on demand wake up scheme of the sink node will all be implemented at the MAC layer. Next layer, the Network layer will provide the ad-hoc routing. Further the application layer will support the command and request service.

There are many built-in motes available like the MICA2 radio stack used in [1], [2], MICAZ mote in [3]. The sensors either can be attached to them accordingly or the sensor node can be designed using the basic hardware.

The operating system provides a crucial role in the motes above mentioned. TinyOS software can be used program the various layers of the motes above mentioned. There is also

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an alternative providing flexibility that is RTOS (Real Time Operating System) which can be used with microcontrollers and can help us to exploit the real time characteristics of the microcontroller as well as take advantage of the OSI layered programming approach. Fig. 3 shows the sensor node software layers.

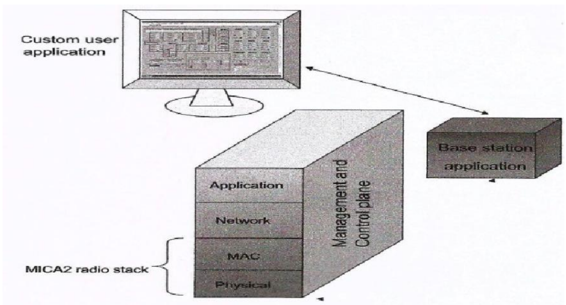

Fig. 3: sensor node software layers

F. Initial Procedures

The base station sends sync signals to the sink nodes which on receiving them broadcasts this message to the robotic nodes. Then the initial query from the base station is broadcasted. The robotic nodes can start their course on receiving these sync signals and the initial query. The sensed data by the robotic nodes is transmitted to the sink nodes using ad-hoc routing. Also at the end of their course the robotic sensor nodes transmit all their sensed data to the base station. The sink nodes store the information until it receives a request from the base station or logs the data to the Bluetooth devices. Also if any of the sensed data crosses the threshold immediate alerts are sent. During their course the sensor nodes go to sleep in the time interval between measurements and the sink node also waits in a low power mode and is reawaken either by the requests or the robotic node ready to send its data. Fig. 4 shows the procedures of the robotic sensor node.

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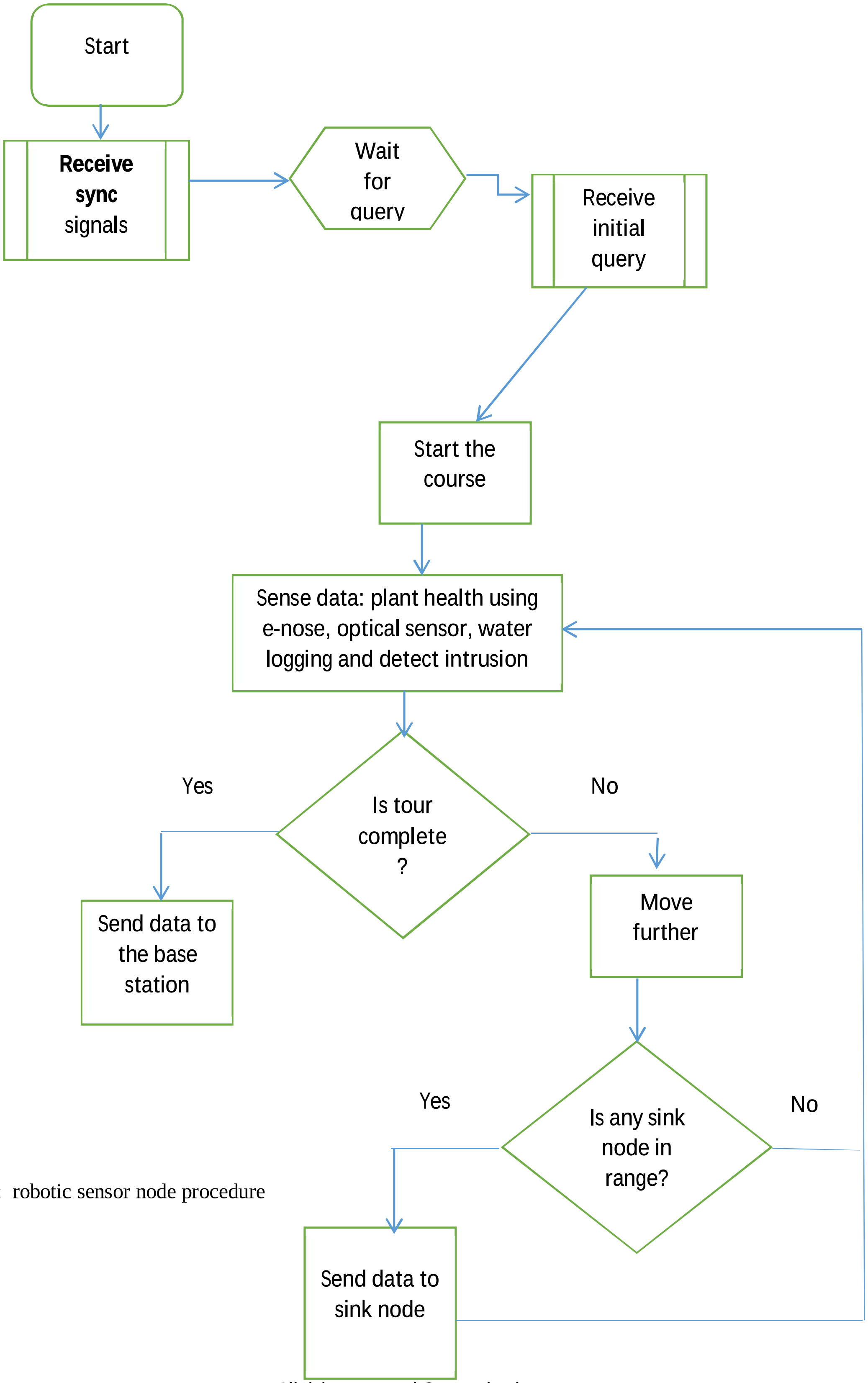

Fig. 4: robotic sensor node procedure

G. Base Station

Base consists is attached via its serial port to a PC. The application on the PC logs the data, extracts useful information and provides the information in many forms including graphs, plots, maps, charts etc. Many built - in softwares can also be used for processing of the received data at the base station. For example Mote-View which acts as a primary user interface between a user and the deployed wireless sensor network. It provides an easy means of logging wireless sensor data to a database, analyzing, and plotting sensor readings. Sensor data can be logged on a host PC, or to a database running autonomously. It supports the MICA, MICAZ platform.

III. CONCLUSION

In this paper, effort has been made to find an efficient way to reduce the initial investment budget, power consumption by incorporating WSN technology with the robotics. This architecture has many advantages namely parallel data storage and transmission path one using the robotic node itself another through the backbone link. It could provide great deal of flexibility, robustness, accuracy and precision especially when the installation is at a large level where one does not want the result to be erroneous because of one or two links disruption. The backbone link is used to store and retrieve the data and also it is used to log the data to Bluetooth devices to which it also sends immediate alerts. Isolation is created between the data storage, linking unit that is the backbone and the sensing unit. This separation allows ease of procedures and distribution of the burden on one node. Basically in this paper we investigated methods that can enhance the agricultural practices in rural areas connecting the small and middle farmers to technology and providing them a method to monitor their farms so that they can face challenges like pest damage, lack of information, irregular seasonal cycles.

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