УДК 681.5

COLLECTING DISTRIBUTED DATA OF PRECISION AGRICULTURE USING WIRELESS SENSOR NETWORK AND UNMANNED AERIAL VEHICLES

G. Krivoulya, A. Lipchansky, Nti Stephen

Kharkov National University of Radioelectronics

Paper presents a collaborative system made up of a Wireless Sensor Network and an Unmanned Aerial Vehicle, which is applied to real-time for Precision Agriculture. The core feature of our system is a dynamic mobile node carried by an Aerial Vehicle, which ensures communication between sparse clusters located at fragmented parcels and a base station.

1. Introduction. The Introduction world's population is expected to double by 2050; world food supply is unlikely to double by doubling the area under cultivation. There are other challenges too, such as decline in the number of farms and a decline in the number of agriculture workforce. Climate change is expected to further aggravate the existing situation. Therefore, for the humanity to survive agriculture has to become smart and Precision Agriculture (PA). The goal of the (PA) is increasing the productivity of the crops while minimizing the use of resources. Given that the agricultural technique has evolved along the millenniums, the only real option to keep increasing the agricultural productivity requires the use of technology: currently, many different automatic means. PA a new concept in crop management has been applied in agriculture for some years now. The objective of the PA is to avoid applying the same management practices to a crop regardless of site conditions and to improve field management from several perspectives; for example, it can help to minimize wastage of pesticides required for the effective control of weeds, diseases and pests and to ensure that crops receive adequate nutrients, leading to more efficient and greener agriculture/ In other words, The PA can be considered as a management strategy that utilizes information technology with the aim of improving production and quality. It therefore differs from conventional farming as it determines variation more precisely and links spatial data to management actions. It thereby allows farmers to tend their farm, crop and practices from an entirely new perspective.

The introduction of Wireless Sensor Network (WSN) nodes for farm monitoring has led to the possibility for supervising how parameters evolve in real time and how they are related. It thereby provides a powerful monitoring tool. Therefore it allows quick reactions or even predictive actions according to the circumstances. This is probably the reason why many applications have recently emerged using WSN in the PA. The measured parameters as temperature, humidity and solar radiation, still remain as the most important ones for PA.

2. Related Works. Most WSNs, such as those described in [1, 2], use humidity sensors for evaluating the specific irrigation requirements for each specific area. Many other topics where WSN technology has been adopted include pesticide control, quality assurance, as well as global monitoring systems [3, 4].

On the other hand, the use of Unmanned Aerial Vehicles (UAV) in agricultural tasks was pioneered by Japan during the 80s, when Yamaha received a request for developing a new kind of unmanned helicopter for crop spraying purposes [5]. UAVs have been later introduced in agriculture applications in order to overcome the limitation of conventional remote sensing systems, such as satellites or manned aircrafts, which have shown being inefficient to address agriculture requirements.

3. Proposed Approach. Recent progress in microelectronic and wireless communications have enabled the development of low cost, low power, multifunctional sensors, which has allowed the birth of new type of networks WSN. The main features of such networks are: the nodes can be positioned randomly over a given field with a high density; each node operates both like sensor (for collection of environmental data) as well as transceiver (for transmission of information to the data retrieval); the nodes have limited energy resources. The use of wireless communications and the small size of nodes, make this type of networks suitable for a large number of applications. In the described situation, the aim of this work is to provide farm managers with a friendly tool that improves situational awareness of their crop by using a WSN linked through a mobile node, carried by an UAV.

4. The use of WSN and UAVs for PA. To develop a monitoring system that collects data using a WSN, and then relays this data through a gateway to a server. At the server side the data are stored and analyzed in order to provide the user with useful statistics and alerts so that user can take various decision. For this application, sensors need to be placed outside, in the open field, where power may not be available. So, sensors should be battery operated. Sensing location may be identified by integrating GPS with each sensor. However, that is not a cost effective solution. In this application, sensors are statically placed at different locations in a field, so the static location of each sensor with its unique sensor id can be stored in the sensors during network configuration and deployment phase. In PA continuous monitoring of sensor data at every minute may not be always needed. Instead, the data may be monitored on hourly basis or at different times of the day, e.g., morning, noon, afternoon and evening. This, in turn, helps in conserving the battery power of sensor nodes. It is also better to use "sleep and awake" cycle of the wireless sensors judiciously to sense and transmit the sensor data in wake-up phases and put the sensors in sleep mode rest of the time. It may be good idea to aggregate the sensor data captured over a period of time at each node before sending the aggregated data to the monitoring station. Generally the monitoring station is located far away from the field; therefore, laying wires for transferring sensor data from field to control station is a costly proposition. But the range of battery-operated wireless devices is also limited. So, multi-hop communication is needed to send data to control station. Researchers are now exploring the use of multi-hop wireless sensor network for this purpose. Considering all these functional aspects and limitations in wireless nodes, low power, and low data rate wireless mesh network is found to be a good candidate for realizing the WSN.

4.1. The use of UAVs. The application of unmanned systems to civil and commercial applications, leveraging a technology which has until now been largely applied to the military domain. Research in unmanned technologies and smart payloads will be key to the use of small and medium size UAVs as an inexpensive tool for executing inspection and surveillance functions, potentially revolutionizing industry. Applications of UAVs include aerial surveillance, search and rescue, border patrol, facilities inspection, management of natural risks, environments, intervention in hostile environments and agriculture. In these applications UAVs and WSN are complementary technologies. UAVs are mobile and have the ability to sense over a large area, but from a high altitude. Sensor network nodes make in-situ point measurements about a very small area. Sensor network nodes have radio communications capability, but with ranges of the order of 1km and at current unit prices they remain a prohibitively expensive approach to cover large areas. Instead we can use UAVs to upload information sensed in-situ by nodes on the ground or to deploy nodes.

The combined use of WSN and UAVs has been already reported, showing their benefits and extendable applications by using fixed-wing aircraft. This approach could present some drawbacks when typical short range and low consumption nodes are used. These nodes will probably require complex trajectories to be performed by fixed-wing aircraft. However, using aircrafts with hovering capabilities allows determining optimal static positions for bridging WSN nodes independently of the required download time. Additional facilities have been reported about the combined use of WSN and UAV's, as the improvement of the navigation system by using nodes positions. Several solutions in combining UAV with WSN to enhance WSN performance was proposed such as using UAV to interconnect between sparse clusters located at fragmented parcels and a base station, using a cooperative connected UAVs *as* sink-nodes to collect data in clusters, using UAV as a mobile node in WSN for emergency situation, or using UAV as an addition solution for charging, deploying WSN nodes.

Figure 1 shows the interaction WSN and UAV for PA.

5. Conclusion. The solution based on a combination of UAV and WSN to monitor variables from fragmented crop fields has been proposed. Problems related to fragmentation of the regions of interest in a wide area such as the impossibility of deploying a fully connected WSN, the large distances to cover and the continuous monitoring of the environment variables can be overcome with the proposed approach. Such problems have been tackled with the basic idea of a mobile WSN node that can periodically recollect the information of the sub-networks deployed in each one of the regions of interest. Since the mobile part is an airborne node, problems related to the nature of the ground are easily overcome. The main contributions of this work are the use of UAVs as airborne communication nodes and the resolution of the problems regarding WSN dynamic configuration when a UAV is approaching to the target area. An *ad-hoc* communication protocol and a communication workflow have been implemented in order to deal with such issues. In addition to this, a user-friendly operator interface that allows handling the system and monitoring data has been implemented. It should be highlighted that cheap and reliable UAV platforms are currently available and they can be easily used in this kind of applications. This work provided the opportunity to test the use of a commercial quadrotor in a real scenario.

References

1. Modelling for Precision Weed Management. In Proceedings of Ciba Foundation Symposium 210—Precision Agriculture: Spatial and Temporal Variability of Environmental Quality, Chichester, UK, 27 September 2007; pp. 182-207.

2.Srinivasan A. Handbook of Precision Agriculture: Principles and Applications; CRC: New York, NY, USA, 2006.

3.Akyildiz I.F.; Su, W.; Sankarasubramaniam, Y.; Cayirci, E. Wireless Sensor Networks: A Survey. Comput. Netw. 2002, 38, 393-422.

4.Yoo S.; Kim J.; Kim T.; Ahn S.; Sung J.; Kim D. A2S: Automated Agriculture System Based on WSN. In Proceedings of IEEE International Symposium on Consumer Electronics, Dallas, TX, USA, 20-23 June 2007; pp. 1-5.

5. Siuli Roy, A. Bandyopadhyay S. Agro-Sense: Precision Agriculture Using Sensor-Based Wireless Mesh Networks. Innovations in NGN—Future Network and Services. In Proceedings of An IT U-TKaleidoscope Conference, Geneva, Switzerland, 12-13 May 2008; pp. 383-388.

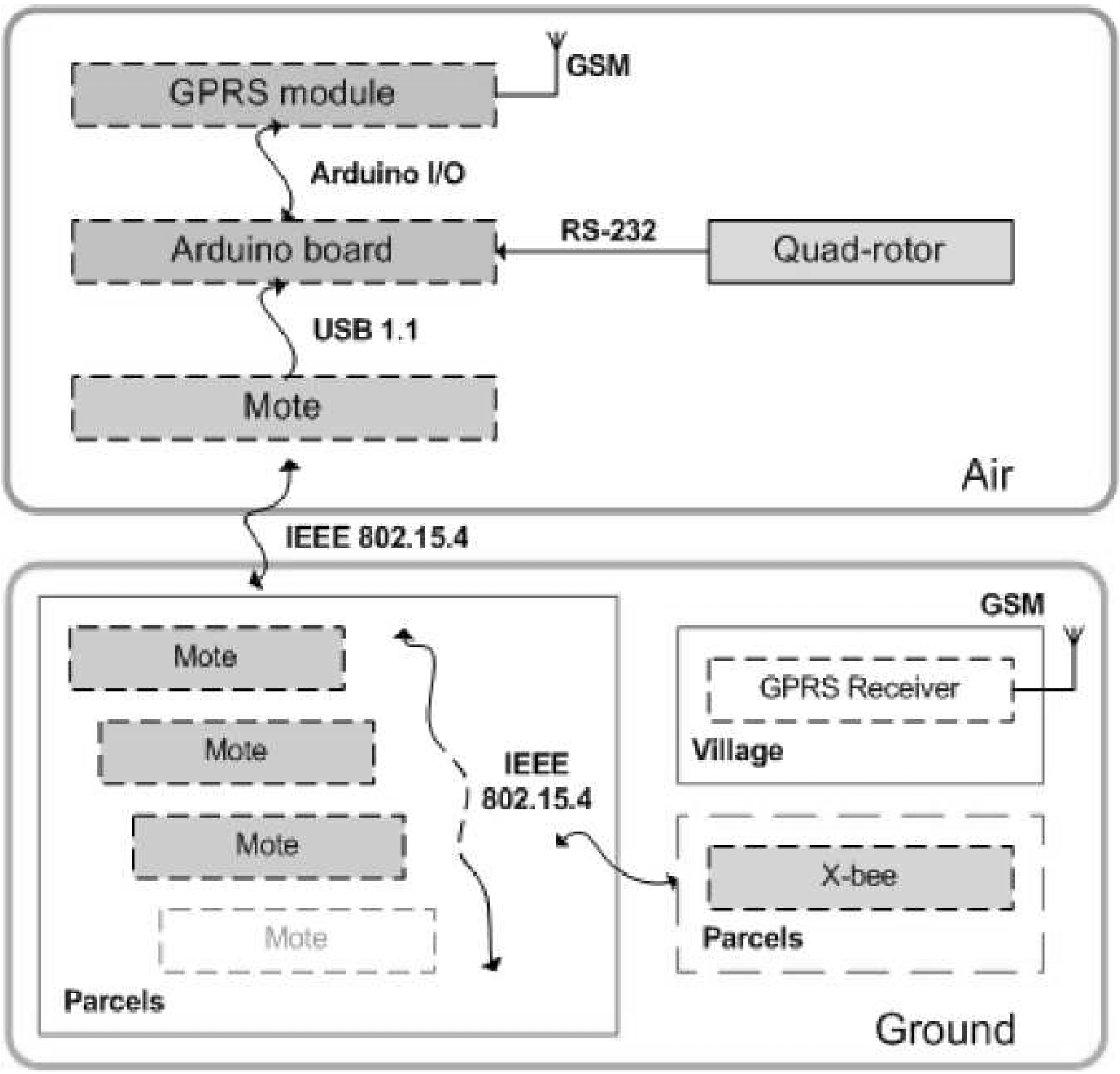

Figure 1 – Proposed interaction WSN and UAV

Аннотация

СБОР РАСПРЕДЕЛЕННЫХ ДАННЫХ ДЛЯ ВЫСОКОТЕХНОЛОГИЧНОГО ЗЕМЛЕДЕЛИЯ С ИСПОЛЬЗОВАНИЕМ БЕСПРОВОДНЫХ ДАТЧИКОВ И БЕСПИЛОТНЫХ АППАРАТОВ

Кривуля Г. Ф., Липчанский А. И., Нти Степен

В статье описана система, состоящая из сети беспроводных датчиков и беспилотных летательных аппаратов, которая применяется в реальном времени для высокотехнологичного сельского хозяйства. Особенностью системы является динамичная связь летательного аппарата с мобильными узлами кластеров, расположенных на фрагментированных участках возле базовой станции.

Анотація

ЗБІР РОЗПОДІЛЕНИХ ДАНИХ ДЛЯ ВИСОКОТЕХНОЛОГІЧНОГО ЗЕМЛЕРОБСТВА З ВИКОРИСТАННЯМ БЕЗДРОТОВИХ ДАТЧИКІВ І БЕЗПІЛОТНИХ АПАРАТІВ

Кривуля Г. Ф., Липчанський О. І., Нті Степен

Стаття описує систему, що складається з мережі бездротових датчиків і безпілотних літальних апаратів, яка застосовується в реальному часі для високотехнологічного сільського господарства. Особливістю системи є динамічна зв'язок літального апарату з мобільними вузлами кластерів, розташованих на фрагментованих ділянках біля базової станції.