AN INTER-CONNECTION MODEL BETWEEN STANDARD ZIGBEE AND ISOBUS NETWORK (ISO11783)

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ABSTRACT

The typical five-step cyclical process of precision agriculture includes soil and environment data collection, diagnosis, data analysis, precision field correction operation and evaluations. Usually, some steps are executed in field, others in the farm office and others in both. This can result in a complex system and consequently in waste of time and high cost in equipment, tools and workmanship. To simplify this process, the challenge is running the whole precision agricultural cycle in computers embedded in agricultural machines, working with different communication technologies, such as wireless sensor network (WSN), specially Zigbee standard, and the agricultural machine bus, ISOBUS (ISO11783) inter-connected. This work considers an inter-connection model between these networks. The model considered is tested in a simulator that has been specially developed for this job and some results are presented herein. However, the results show that an efficient inter-connection is not possible with common devices such as bridges or converters. It is necessary to develop a new concept for these networks and a possible complementation to the ZigBee or ISOBUS standards. With an efficient inter-connection, it will be possible for the agricultural machines to move through the crop; at the same time, they can scan the soil and the environment, besides making the necessary corrections, reducing time, costs and workmanship.

Keywords: ISOBUS, Wireless Sensor Network. Precision Agriculture, embedded computers,

INTRODUCTION

One of the targets of sustainable development in agriculture is the maintenance of natural resources and agricultural productivity for a long period of time with the minimum of adverse impacts on the environment.

Sachs (2000), when studying the ways for agricultural sustainability, shows that it is not possible without adequate resources management and intensive use of high technology, capable of generating products with high aggregated value. Information management has become a vital edge for production efficiency for all industrial and agriculture segments.

Nowadays a network technology sets is available as well as digital communication to make the information management in agriculture easier. Some of these technologies allow us to get information on crops in order to compare it with previously established models and to generate some corrective tasks. As an example, Pee and Berckmans (1996) and Shimizu and Yamazaki (1996) describe sensorial techniques to get information such as photosynthesis, hydro-potentials, flow of water and nutrients in caulis and distribution of assimilated substance by the plant.

Even though these technologies are available, it is not possible to take full advantage of them, because of the way they have been developed; they are not integrated among themselves. The search for this integration will certainly lead to more productivity and it will then turn the agriculture more competitive.

Precision Agriculture is defined by Pierce and Nowack (1999) as “the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production for the purpose of improving crop and environment quality”. For this end, different kinds of techniques are used in ground and environment monitoring. For example: there has recently been a growth in the use of wireless sensor network (WSN) in agriculture for environment monitoring.

The microprocessors development allowed the production of small sensors powered by batteries, that communicate between themselves by a radio system using communication protocols developed in specially for this end (Gonda and Cugnasca, 2006), as in figure 1. They are auto-configured, auto-organized and they are considered fault-tolerant because they work cooperatively. According to Fukunaga et al. (2007), the cooperative work, when performed with a great number of sensors allows us to get a certain amount of information, that despite being individually insignificant, make it possible for a lot of new functions, never implemented before, to be created.

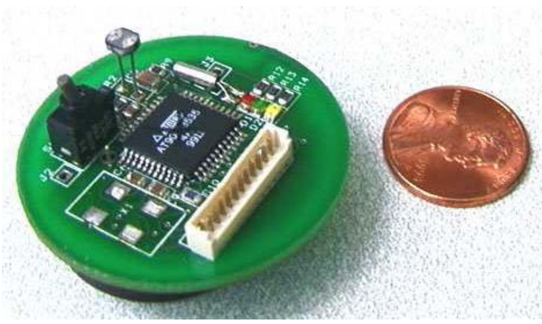

Fig. 1. A wireless sensor. From http://robotics.eecs.berkeley.edu/~pister/SmartDust/

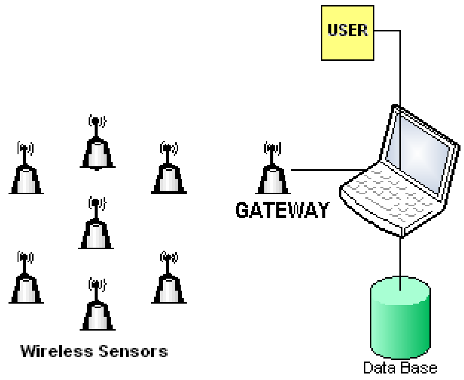

Fig. 2. WSN application example.

The main characteristics of WSN are: long-life small batteries; reduced dimensions; covering large areas; different kinds of sensors; use in difficult access areas; fault-tolerant; small memory; and limited hardware. They use a complex routing system. The information jumps from sensor to sensor until it arrives at its destination thus reducing the transmitters energy consumption. Because of this, they use several kinds of communication protocols such as ZigBee, that follows the IEEE 802.15.4 standard.

According to Kinney (2004), the ZigBee was created to:

• Provide low battery consumption (at least 6 months in a typical application).

• Configure the application software to manage the consumption of batteries through active/inactive cycles.

• Reduce the device costs and its implementation.

• Increase the density of nodes in the network.

• Make the implementation easier (Figure 2).

THE PROPOSAL

The need of having more and more distributed systems in the environment, specially in the field, must be highlighted. For this, it is necessary for all system components to be connected between themselves in order to exchange data in a practical and efficient way (Sung et al., 2007). Zhang (2006) advocates this idea pointing out that “the need to interconnect diverse network technologies turns the world more `pervasive'". In the same way, Jensen (2007) draws attention to the need of distributing the processing among the agricultural machines

Some works consider the possibility of using WSN in equipment installed in vehicles, in which the problematic of the sensor communication in mobile points should be resolved. Vieira et al. (2003) and Nakamura et al. (2005), for example, when approaching WSN, conclude their research by saying that their work needs to be complemented by other works that consider the nodes mobility; Dulman (2003) presents a technique of direct routing in a mobile WSN node; Luo (2005) considers as solution the existence of mobile nodes.

It is believed that the configuration in which sensors could directly send the collected data to a computer embedded in a moving vehicle, while the vehicle gets into sensor signal reach, could be more efficient. This would make it possible for some tasks to be defined and executed in the vehicle computer.

To resolve this, an interconnection between two networks should be considered: the WSN in the crop field and the ISOBUS, a network embedded in agricultural vehicles. On the one side, the connection would emulate an ISO 11783 (ISOBUS) node, a network embedded in the tractors based on Control Area Network (CAN) protocol as a sensor information data base. On the other side, it would function as a ZigBee collected node, as a kind of gateway working in central node of a WSN, as illustrated in Figure 3.

Many aspects need to be considered for proposal validation such as network life (energy consumption), operability, trustworthiness, safety, security, and performance among others. There are many works about evaluating these aspects both in WSN and in ISOBUS. Yet no work resolves the performance issue of both networks working together. This relevant proposal is the concern of this paper. Other aspects should have to be evaluated in future works.

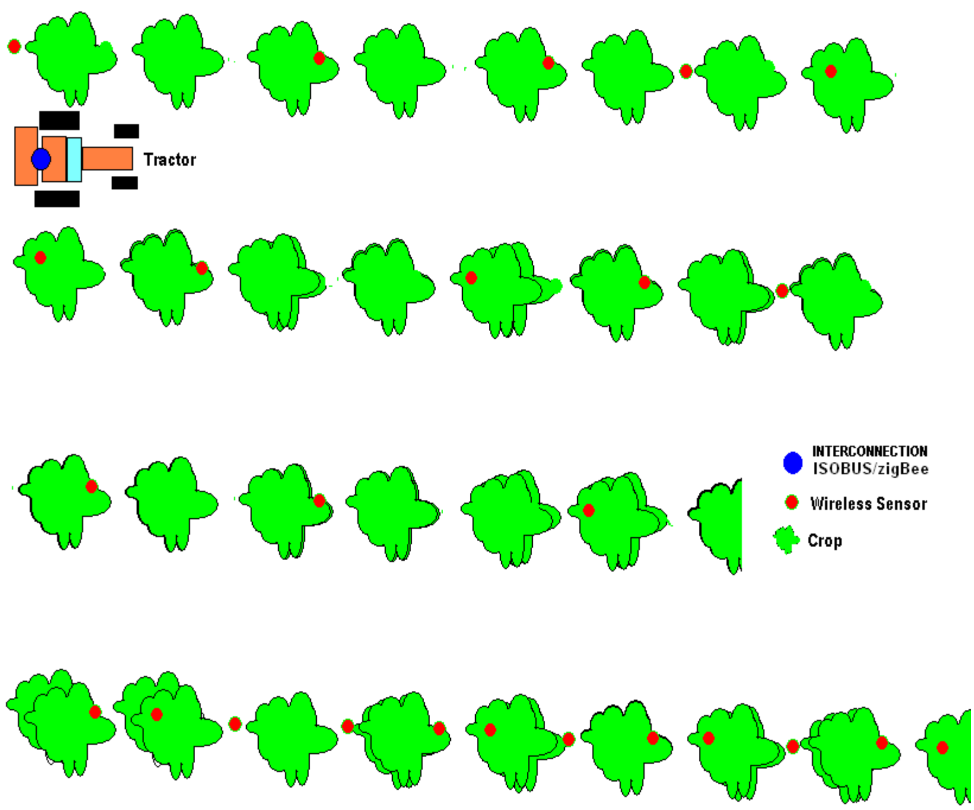

Fig. 3. A hardware proposal in which sensors send information directly to tractors.

MATERIALS AND METHODS

In the first phase, this work analyzes the ISOBUS and ZigBee Open Systems Interconnections (OSI) reference models. The purposeis to define which device is the best for the interconnection: converters, routers, bridges or gateways. In the second phase, simulations were executed to validate the proposal.

Many aspects must be resolved before developing an interconnection device such as the possible WSN architectures which have to be tested in many kinds of agricultural cultures and in many environments. This would result in a great amount of tests. The alternative for validating the proposal is to develop a simulator in a computational environment where the variability of applications is taken into account (Pagano et. Al., 2009). Some situations in the simulations could still be compared by practical tests in which the same conditions are reproduced.

There are many kinds of simulators for WSN and ISOBUS, but none of them estimates an interconnection between both networks. The work to integrate two of these simulators, one for WSN and another for ISOBUS, would be as complex as to develop a new simulator.

The architecture shown in figure 4, with a virtual terminal, a sensor ECU, a gateway, a collecting ZigBee node and a cluster tree topology WSN, is configured in the simulator. The simulations have as objective to evaluate the efficiency of sending generated data from wireless sensors to virtual terminal in ISOBUS network.

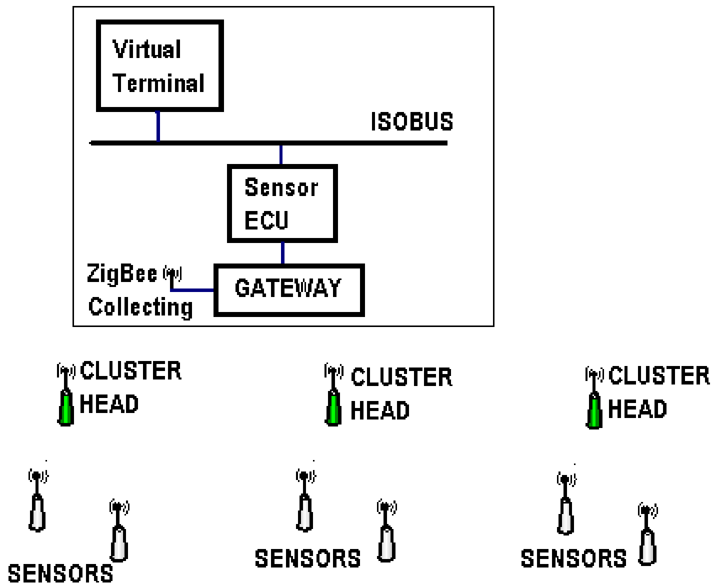

Fig. 4. Network configured in Simulator

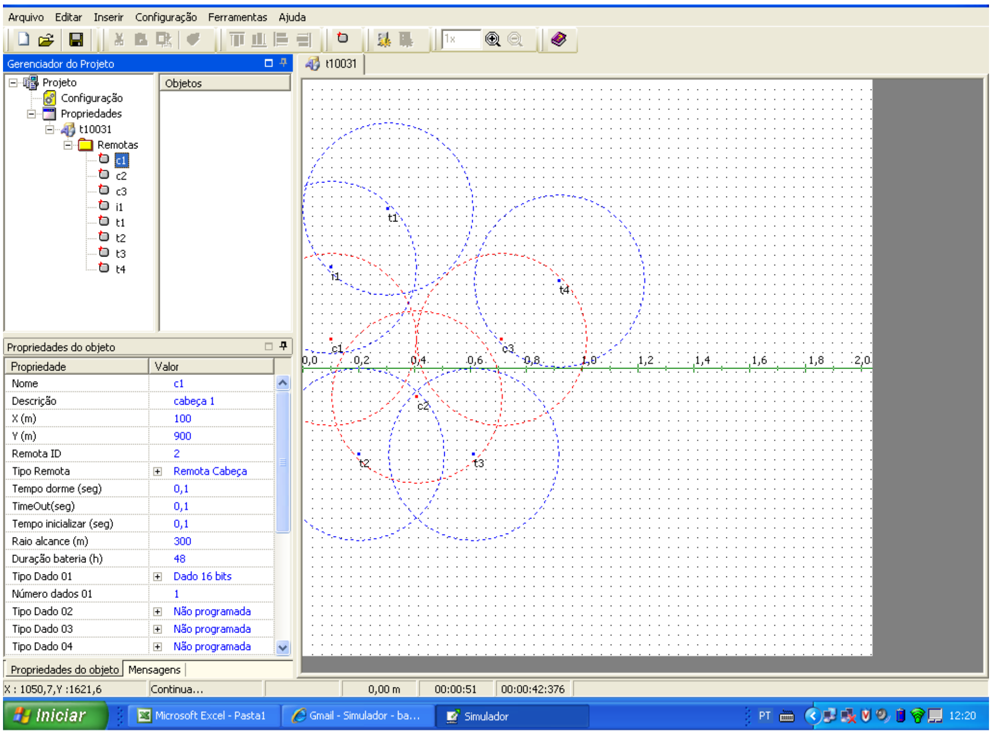

Fig. 5. Work Area in Developed Simulator

Besides the intrinsic aspects of interconnection (timing, data management, signaling, etc), of protocols (timing, delays, overhead, size of data packages, middle access, speeds, etc), the simulator (Figure 5) in this paper must contemplate aspects such as:

- Many WSN topologies.
- Variability of the environment conditions (geographic position, topography, culture, etc).
- Sensor variability (transceiver power, battery charge, sensing elements, amount of data, processing capacity, etc).
- Variability of the implementation (topologies, tractor speed, distances among sensors, etc).
- Configuration of the sensors (way of operation, time of cycle, synchronization, etc).

In the first step, the considered simulator will have to create an initial scene defined by the user (a set of initial values for the variables), and then in a second step emulate the networks and interconnection operation, thus determining the behavior of the performance of parameters. In the next steps, the second step with new scenes (creating new sets of values) would be repeated. The user will have to define a statistical distribution (normal, triangular, rectangular or other distribution) for each variable of the scenes, in which the simulator will generate these new values.

The simulations have madden based in a typical future agricultural application scene. Some of their aspects are shown in table 1.

Table 1. Some scene aspects configured in simulator

Aspects	Value	Observation
field area	11ha	
Tractor speed	20km/h	passing among the plants lines
Topology	33 clusters tree	3 or 4 sensors each cluster
Distances between sensors	20m to 35m	
Sensing elements	1 to 6 per node	
intervals to send	1s to 10min	

RESULTS

These protocols work very different in every layer of ISO model. This allows us to conclude that gateways is the best interconnection implementation. Some results of the simulations are compiled in table 2. It shows the time delay between the sensor send a data and the terminal virtual receive it.

Table 2. Simulation Results File Example

Sensor(ID)	Data sent	Data received	Faults	Delay average	Delay Max.	Delay Min.	attempts
	(unit)	(unit)	(unit)	(seg.)	(seg.)	(seg.)	(unit)
1	2756	2756	0	0,42	0,62	0,41	2992
2	3441	3441	0	0,41	0,62	0,40	3677
3	6180	6180	0	0,37	0,56	0,36	6404
4	3440	3440	0	0,42	0,64	0,41	3664
5	2085	2085	0	0,43	0,62	0,42	2309
6	695	695	0	0,47	0,63	0,47	709
7	695	695	0	0,43	0,87	0,41	709
8	695	695	0	0,43	0,58	0,42	709
9	695	695	0	0,43	0,59	0,42	697
10	1390	1390	0	0,33	0,35	0,32	1390
11	695	695	0	0,43	0,62	0,42	696
12	2085	2085	0	0,43	0,43	0,41	2085
13	1390	1390	0	0,43	0,54	0,41	1392
14	695	695	0	0,43	0,42	0,40	695
15	695	695	0	0,24	0,33	0,23	696
16	2085	2085	0	0,24	0,25	0,23	2085
17	695	695	0	0,19	0,19	0,18	695
18	695	695	0	0,25	0,34	0,24	696
19	695	695	0	0,25	0,25	0,25	695
20	695	695	0	0,25	0,25	0,24	695
21	1390	1390	0	0,31	0,33	0,30	1390

DISCUSSION

The ISO 11783 standard considers a sensor Electronic Control Unit (ECU) and a Network Interconnection Unit (NIU) to interconnect fieldbus networks. A possible good solution to implement the interconnection could be a special NIU for ZigBee in addition to the sensor ECU functions.

The simulations objective is the interconnection operational viability, but many other aspects can be analyzed with the results of the simulations, specially WSN aspects such as:

Topologies: WSN allows for three kind of topologies (tree, cluster tree or mesh) while ISOBUS allows for only bus topology. Using the topology in cluster tree in agriculture is the most recommended for WSN, because in the proposal, the collecting node is in a mobile vehicle that would not always be in the sensors reach. The topology in cluster tree would allow us to create buffers with historic data inside some sensors (cluster head), close to the tractor way, waiting for the tractor to pass. The cluster head would then send the buffer information. Despite being adequate, this topology has two main limitations that need to be considered. Firstly, the buffer limits. Secondly, the access to data, which is not on-line. *Would these limitations affect the performance of the applications?*

Loss of data: The agricultural environment can be considered relatively hostile for electronic devices such as wireless sensors. They suffer with bad weather, vandalism, animal actions, dust and growing of the plants in the crops. All of this can cause complete or partial loss of data. The simulations must foresee possible losses of data and assess the effect of these losses in the application. Another reason for loss of data is the lack of synchronization between the way ZigBee and ISOBUS work. To synchronize the data, it is necessary to create intermediary buffers.

Routing: The simulations results must permit to assess many routes that the sensor data use to arrive to the collecting node (in tractor), in special, a mobile node. It is also possible to evaluate the effect of a route exchange during the passing of the tractor.

Tractor Speed: The tractor speed is defined by the kind of task and the machines that are been used. However, the faster, the lesser time the tractor takes to receive the data, because the tractor remains less time within the cluster head radio reach. *Could this turn some applications impracticable?*

Network lifetime: Although the wireless sensor battery has been dimensioned for a long life, the more intense the use of some nodes the shorter the batteries life time, leaving part or the whole network inoperative. The simulations will have to foresee these situations and their results must be assessed.

Types of Sensors: Different types of sensors have different data acquisition rate with different temporizations, generating different amounts of information. The simulator will have to allow for the assembly of networks with the most diverse types of sensors and the most diverse applications.

Positioning of the Sensors: The sensor positioning has direct influence on the routes to be established. In addition, the topography has a significant influence on the route establishment. Because of this, the topography effects must be simulated.

CONCLUSIONS

Only with a ZigBee/ISOBUS gateway was the networks interconnection possible. The simulations show us that the interconnection is technically viable. Besides, it is possible to send data directly from sensors to a virtual terminal. The detected delays in simulations are fully acceptable for the considered scene, specially when the interconnection is used in a real time application.

To verify the efficiency of the network interconnection between ZigBee and ISOBUS for use in agriculture, it is necessary to make a lot of checking to cover all agriculture application cases, combining different configurations, topologies and architectures. In this way, practical performance tests would take months, beside the high costs of assembling the most diverse combinations. The simulator considered in this work could emulate the interconnection to evaluate the performance of both networks in diverse scenes in few days. The scenes must be generated by the simulator with data from a real typical application.

Some of these scenes, chosen randomly, will have to be reproduced in practical tests, crossing the results with data to be obtained by simulations and the consequent adjustments in the emulations.

The results of the simulations must be evaluated and complemented in future works to determine on which scenes each application must be used, and on which interconnection proposal is efficient and has satisfactory performance. In other future works, the interconnection necessities must be considered, so as to contribute to a future ISO 11783 standard complementation. Besides some works to determine the best way to make the interconnection should be performed.

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