

A HYBRID NETWORK FOR AUTOMATIC GREENHOUSE MANAGEMENT

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ABSTRACT

A greenhouse is a building in which plants are grown in closed environment. Greenhouse management is controlling of several greenhouse. The wireless section is located in the indoor environment where great flexibility is needed, particularly in the production area of greenhouse. Instead, the wired section is mainly used in the outside area as a control backbone, to interconnect the greenhouse with the control room. An integrated wired/wireless solution is to use the advantages of both technologies by improving performances. In the wired section, a controller area network (CAN) type network has been chosen on the account of its simplicity, strongest, cheapness, and good performances. for the wireless part, a Zigbee type network has been chosen. The SCADA system is to monitor and control data in a simple way. To maintain the optimal conditions of the environment, greenhouse management requires data acquisition using the SCADA (supervisory control and data acquisition).

Keywords: CAN bus, zigbee, SCADA, greenhouse parameters , wireless sensor networks.

1 INTRODUCTION

A greenhouse represents a strange kind of agricultural environment characteristics by the presence of several I/O devices (i.e., sensors and actuators) and control devices (e.g., SCADA). Requirement of human involvement is less compared to open air agriculture for to provide water for irrigation and manures. Greenhouses represent a closed environment which can be strictly controlled by humans in order to provide best conditions for the growth of plants. wireless sensor networks (WSNs) in agriculture have recently received great attention, and their use has been intensely investigated by few authors . Owing to the use of sensors, it is possible to monitor several environmental parameters such as air temperature, ground humidity, light, or the absorption of manures. The knowledge of such parameters is of great importance since it allows the farmer to perform the most suitable operations in order to improve the growth of plants and productivity and low cost, crops are grown within a short time duration in greenhouse. Sensors, both wired and wireless, are connected to a fit network which allows data gathering and their use by a suitable management module.

For this kind of applications, there are several advantages offered by a wireless system if compared with a wired one. They can be synthesized inside the concept of flexibility. Actually, the large extensions of the cultivated fields and the need for cyclically alter a type of cultivation or to move it from a lot to another one make wired systems too firm and hard to modify. Some species are grown only in some seasons, that types of farms requires careful management of several parameters, through data acquisition

in every greenhouse and their transfer to a control unit which is usually located in a control room, keep away from the production area. All these data are treated by a Supervisory Control and Data Acquisition (SCADA) system which, through incessant variable monitoring, determines the actions to perform occasionally in order to maintain the optimal conditions of the environment.

Now a day, the data transfer between the greenhouses and the control system is mainly provided by suitable wired communication system, such as a fieldbus. And fully wireless network can also introduce some disadvantages, for example, the need for a periodical modify of batteries, the presence of signal spreader problems which can arise on long distances. Then, the use of hybrid wired/wireless technologies appears to be currently the best tradeoff solution .

The wireless section is located in the indoor environment where great flexibility is needed, particularly in the production area inside each greenhouse. In such a way, it is possible to use the characteristics inter connected to high scalability, cheapness, simple setup, and mobility of devices whose position can be easily modified. Instead, the wired section is mainly used in the outside to interconnect the greenhouses with the control room. The location of greenhouses being steady for long periods.it use a wired communication infrastructure which is well recognized for

this kind of applications, offers a high bandwidth, and is stronger than a wireless one. The implementation of a wireless strength, in fact, would have required the dislocation of several intelligent nodes that are able to route data coming from different greenhouses toward the control room. also, the number of these nodes would have to be high enough to provide a certain level of unemployment for both fault tolerance and performances, to allow multiple paths, and to avoid blocks. An integrated wired/wireless solution allows one to use the positive aspects of both technologies by improving performances and easily manages the management problems.

2 SYSTEM ARCHITECTURE

The system to be controlled is made up of several greenhouses distributed in a field. Each greenhouse is used for the manufacture of several types of plants, which can vary according to the season and to the requests from the market. Each greenhouse is equipped with several sensors and actuators which perform all the performance requested for the correct growth of plants.

Sensors are mainly used for the measurement of temperature and humidity, which represent two main parameters inside the greenhouse. Since this is a closed environment, exact measurement and control of parameters, whose value can powerfully affect the state of the system, are significant. For example, the humidity of the ground is important for the correct growth of plants, and its measurement is important in order to assess the quantity of water to distribute in the greenhouse. also, air humidity plays an important role since a too high value, together with high temperature, can reason the production of shape and the rapid death of few plants. On the other hand, a too low value of air humidity can damage plants which need a tropical-like climate. Light, whose intensity can affect the growing speed. High moisture would destroy the growth of crops. High temperature leads to affect the crop yields.

Actuators are mainly used to alter the environmental conditions through the activation of irrigation valves, air humidifiers, cooling fans, and water pump. Actuators are put in action by commands sent by the control system which integrates all the environmental information through suitable control algorithms.

The control system is a key point to consider. while, in the past, control strategies in greenhouses were very simple and mainly based on the use of timers, currently, more urbane approaches which exploit the same techniques used in industrial mechanization are used. For example, the use

of SCADA systems which, too process control, provide also other functionalities that are very useful in greenhouse management. In particular, the following two great significance.

1) Graphical user interface. The graphical user interface allows one to represent the whole system and to display the status of all or part of the field. This allows the human operator to assess how the system is working and to get well quickly from irregular conditions.

2) Historian module. The historian module allows one to record all significant parameters and to display them as suitable graphs. This can be very useful to learn the reasons of some problems which occurred in the field. For example, in the case a illness that arises on some plants, an analysis of the past values of some flexible can be helpful to discover the cause which has triggered such a disease.

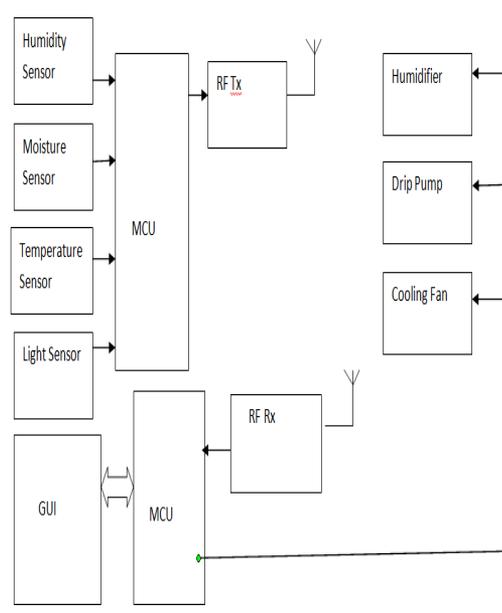


Fig. Layered architecture of the control system.

However, the most significant part of the SCADA is the control part, which is based on closed loops and is dependable for the system development. The growth of a plant takes, certainly, a long time, and control parameters must be continuously modified during the various phases. Moreover, controlling the development of a plant is not an exact science; thus, several randomness can arise. This implies that the process cannot be fully automated and that an operator must interact with the system when required.

The main environmental parameters are

temperature, humidity, moisture, light inside the greenhouse would be measured by the using of sensors. The output of this parameters provides the daily set points. sensors outputs will be displayed in analog form,so for our easy measurement we need to convert analog data into digital form . This done by using analog to digital converter in PIC.

The sensed data transferred to control unit via wireless link, i.e.,zigbee.received information will be stored in the SCADA. This SCADA will monitor the sensor value, if it is in abnormal then it run the actuators using PIC IC.

3 CAN BASED BACK BONE

The CAN bus was originally designed to be used within road vehicles to solve cabling problems arising from the growing use of microprocessor-based components in vehicles. Owing to the low price of CAN bus and its ability to support real-time communication, CAN is nowadays widely used as an embedded control network to connect several control units, sensors, and actuators in a dispersed manipulatel system. In the greenhouse application, CAN is used as a low-speed determination for the addition of all the information present in the system.

One of the reasons which justify the success of the CAN lies in the helpful precedence based bus negotiation mechanism it implements. Any letter contention on a CAN bus is

deterministically determined on the basis of the precedence of the objects exchanged, which is fixed in the identifier field of

the frame. Thus, the priority of a message is the priority of the object it contains, spoken by the identifier, which represents the significant part of the CAN frame.

The arbitration mechanism present in CAN requires a short length of the bus (which is typically 40 m at 1-Mb/s bit rate) in order to allow all nodes to sense the same bit. This way, the system can behave as a form of large AND gate, with each point able to check the output of the gate. The identifier with the loweststastical value has the highest precedence, and a nondestructive bitwise arbitration mechanism provides the collision resolution.

The priority of a CAN message is static and systemwide common ,and it is linked to a variable. This means that each edge can carry nly a variable each time, so that different variables need different frames. For this cause, each frame has a small dimension, contains only a few data bytes (8 B at maximum), and is very handle for applications at the field

level.

The maximum achievable bus line length in a CAN network is limited mainly by the delay of the bus line if compared with the bit duration: The bus length must be reduced as the bit duration decreases (i.e., the bit rate increases). The bit rate versus the bus length in a CAN network is shown in Fig. 4.

The short length of the bus may represent a strong limitation for applications different from the automotive ones. For exam- ple, in greenhouse control applications, the duration of the bus can be up to 200 m. In order to manage with this length, the bit rate should be reduced: 250 kb/s can be considered a correct value, but in the greenhouse, the flex speed has been limited to 100 kb/s in order to provide some additional noise protection. However, a low bit rate is not a problem for the application considered here since all processes are featured by a very low dynamics and exchanges only little information. Even with a high number of plans, the traffic produced is limited and does not require a large bandwidth.

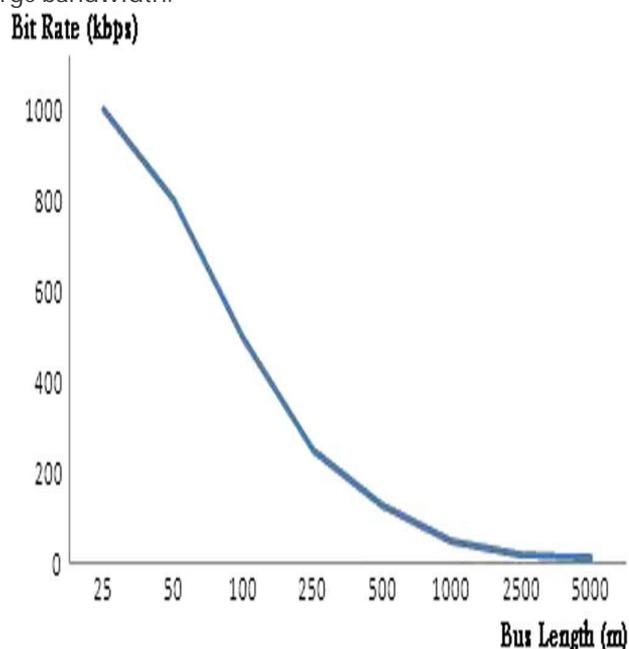


Fig. Bit rate of a CAN bus versus the bus length.

CAN standard specifications are limited to layers 1 (Physical) and 2 (Data Link) of the International Organization for Standardization/Open System Interconnection (ISO/OSI) reference model. The third layer (the Application Layer, according to the three-level architecture that is widely accepted for field level communication systems) has not been particular in the standard, so that several special application layers have

been proposed and adopted . SDS provides the following service sets,

- 1) *Read/Write*: allows the client to read/write the value of a device;
- 2) *Event*: allows exposure an event in a device;
- 3) *Action*: sends a command to a device for carry out an action;
- 4) *COS ON/ COS OFF*: information an ON/OFF-type change of state (COS) in a device;
- 5) *Write ON/Write OFF*: permit the user to set/reset the form of a device;
- 6) *Connection*: used to ON/OFF a connection with a spe- cific logic address;
- 7) *Channel*: used in arrange to set up multicast or peer-to-peer communication.

Even if restricted to a few services, this set is able to implement all functions required for the greenhouse.

Read/Write services are used to read the value of variables produced by sensors and write a value into an actuator (e.g., the speed of a fan).

COS ON/OFF services are used to point out that a 1-b variable has changed its value (e.g., a limit switch has been pressed or a trigger circuit has fired).

Write ON/OFF services are used to energy ON/OFF a device (e.g., to open an irrigation valve or turn on a heater).

Event and *Movement* services are used, for example, to indicate a confining request from a mobile sensor and command a beacon message to start the localization.

Finally, *Connection* and *Channel* armed forces are used during the arrangement of the system in order to set the logical channels between the SCADA and the field devices.

Starting from the SDS conditions, these services have been implemented into the CAN devices which have been obtained by using cheap microcontrollers with embedded CAN communication capabilities. As confirmed , all CAN devices are used to connect the SCADA system with the actuators and CAN/ZigBee bridges.

4 ZIGBEE BASED WIRELESS NETWORK

The need to deploy several mobile sensors in each greenhouse has pushed toward the use of WSNs. In addition to the different contender, we have chosen a ZigBee based network on the account of several useful visage it offers¹⁾ such as low cost, small dimensions, suitable range, and very small power demand. The last visage is really very

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agreeable for a WSN, as it guarantees a long battery life and decreases the maintenance requirements.

ZigBee is based on a Carrier Sense Multiple Access with Collision Avoidance protocol and operates on three distinct bands. This almost used is the industrial, scientific and medical (ISM) 2.4GHz band, which the longest range (more than 100 m open air) and offers 16 different communication channels with a 250-kb/s bit rate. The access of few channels allows avoiding interferences in addition to the communications in different greenhouses, which can be ordered as independent personal area networks (PANs). Two different kinds of devices are considered: full function devices (FFDs), which can work as the master of the PAN (called PAN coordi- nator) or as routers, and decrease function tools, which can only communicate with an FFD to interchange data. Different topologies are tolerate something, including star, mesh, and cluster tree. In this effort , the star topology has been used, subsequently in each greenhouse, a CAN/ZigBee bridge exert effect as the PAN coordinator in order to control the data acquisition from the sensors; thus, all the wireless devices only interchange data with it.

The ZigBee architecture is based on a four-layer stack: Physical, Data Link, Network, and Application layer. In the greenhouse, a little adjustment in the ZigBee stack have been introduced in order to lighten the implementation on small devices.

First of all, the Network Layer has been detached, as each PAN is based on a star topology and no routing is necessary. Second, an SDS-like Application Layer called ZSDS has been implemented. This makes a common service set available to all plant, so that the SCADA can handle, in the identical way, the data coming from both wired and wireless networks. The building design of each wireless node is shown in fig.



Fig. Interfaces between MAC and ZSDS layer.

The application support (AS) middleware links the Appli- cation Layer directly to the Medium Access Control (MAC) sub layer and provides two main functions:

Keeping the tables containing the registered embed- ded objects which define the functions implemented into the device;

2) Doing the mapping between MAC 64-b addresses and network 16-b addresses assigned by the PAN coordinator.

These functions are tolerate something through services provided by the following two entities:

- 1) AS Data Entity, which provides a data transmission service required for the transport of application protocol data unit between two devices belonging to the same network, also including some mechanisms for a dependable data transport;
- 2) AS Management Entity, which produces the binding of the devices, keep going the AS information base database of the handled objects, and supports the mapping between the addresses in the two layers.

The interface between the Application Layer and MAC .

Since each ZigBee tool that can contain, as shown in Fig. 7, several embedded objects(up to 32), each one will order ,in addition to the 16bit network address, other 5bit embedded object identifier (ID) for its addressing.

SDS defines two types of packet.

- 1) Short Form: used for single binary devices to implement COS_ON/OFF and Write ON/OFF services. It can also be used for Read/Write services when subject to a single variable.

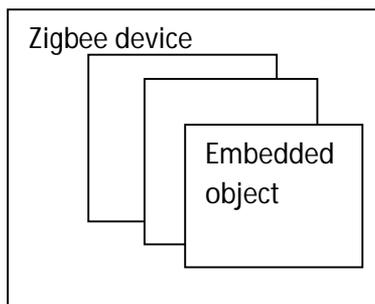
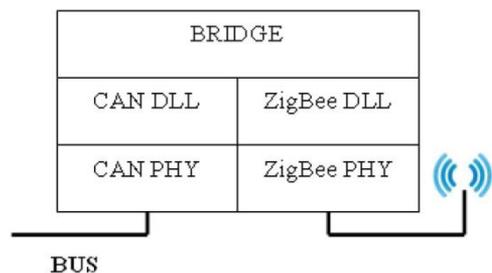


Fig .Embedded objects in a device



Long Form: used when a single ZigBee device is connected to more than one sensor and needs to send sum total information or during the device shape phase. It is also used for all the other services which are available in SDS.

The access in the Zigbee MAC frame, of a data field greater than CAN allows one to send several various information, coming from various sensors, inside a single frame. This is a great merit from the point of view of power consumption because, when a node is alert, it can send into a single frame the information given by few sensors instead of waking up few times. In

the original SDS protocol, a longform packet must be incompleted into few subsequent MAC frames on the account of the small payload (8 B maximum) carried by a single CAN frame. This is not important for ZigBee because each MAC frame can carry up to 102 B, which is several times greater than the CAN payload. Regardless, it must be considered that the network in the greenhouse is hybrid (CAN/ZigBee) and that the agreement between the two protocols must be maintained. For this reason, the need to disintegrate frames when required has been moved into the CAN/ZigBee bridge.

5 BRIDGE

The bridge between the wired and wireless sections of the network is a fundamental component for the proper functioning of the system since it must allow for a correct data exchange between varied networks. Its main task is to handle the translation between the CAN and ZigBee Physical and MAC protocols. The design is shown in Fig.

Protocol adaptation in the Physical Layer is trivial since it is performed by hardware components which deal with all the operations required. Instead, protocol conversion in the MAC Layer need not only suitable data encoding/decoding and encapsulation/decapsulation but also harmonization of two different behaviors. In individual, two of the main issues solved by the bridge refer to the different lengths of frames in CAN and ZigBee, and in a different way, an confessing is provided.

With reference to the first problem, it must be considered that a CAN frame payload is limited to 8 B (this requires fragmentation of longer packets sent by the Application Layer), whereas a ZigBee support can contain up to 102 B in the payload, which agree to few CAN frames. For this reason, fragmentation/reassembling of frames must be handled in the hybrid wired/wireless network.

With reference to the second problem, in CAN, an "Ack" is only sent through on the fly modification of a suitable bit inside the frame being transmitted, while in Zigbee, an Ack is a specific message sent by the corresponding node after the reception of a correct frame.

The two issues are correlated, since fragmentation of a frame has an impact on the way Acks are handled; thus, they involve an integrated management by the bridge. In order to filter the problem and the solution proposed here, let us judge the case when an SDS long-form packet (SDS-LFP) has to be sent from the application in a Zigbee device to the SCADA through the CAN-based infrastructure. initial of all, the packet is transferred to the bridge in a single frame (assuming its length is shorter than 102 B) through a confirmed service at the Data network Layer. This requires the Zigbee compliant section of the bridge to send an immediate Ack after the reception of the enclose. However, this Ack only confirms part of the path followed by the edge, which could suffer some problems in the wired part of the network. Alternatively, if the link waited, before transmitting the Ack to the ZigBee dispatcher, that all fragments of the frame would have been confirmed on the CAN side, this could demand for a too long waiting time with possible expiration of time-outs.

The solution adopted for the bridge is based on a two-step acknowledgment. As soon as a ZigBee outline arrives to the bridge, an urgent Ack is sent to the sender Zigbee machine. This Ack message will not be forwarded to the Application, having only the goal to avoid unnecessary retransmission caused by time-out conclusion. Then, the frame is fragmented inside the bridge and transmitted through the CAN bus. Behind the reception of the acknowledgments for all the fragments, the bridge will send an exact aggregate Ack to the Zigbee sender, which will be transferred to the dispatcher Application as a service confirmation. This system is shown in Fig. 9, which shows the chain of messages in both the wired and wireless sections of the network.

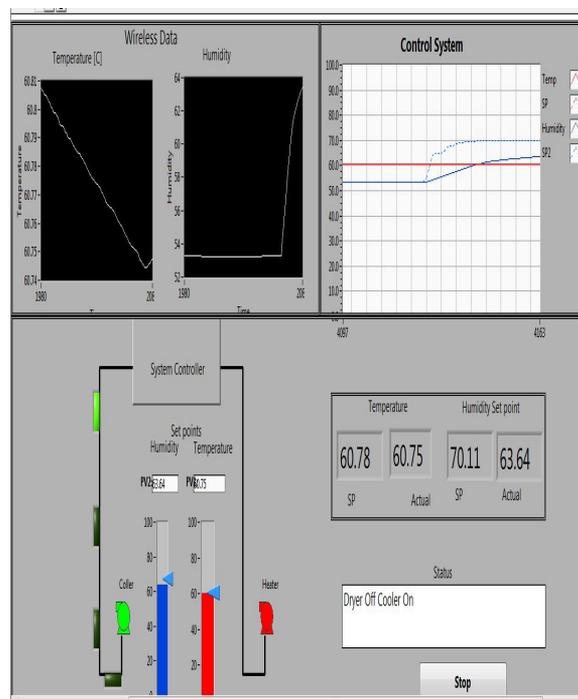


Fig.

Errors in the X coordinate.

A.Single- Component Test

Here, all components have been tested separately in order to find happen problems in thefullfillment. Some subsystems, e.g.,CAN, Zigbee, and bridge, have displayed very satisfactory appearance, as they were able to carry data correctly, working at the designed bit rate. The SCADA technique has been subjected only to a functional test since it is strongly affected by the specific implementation of the control buildings. These models must be defined through a strict cooperation between the farmer and the control engineer and still represent a partially open issue.

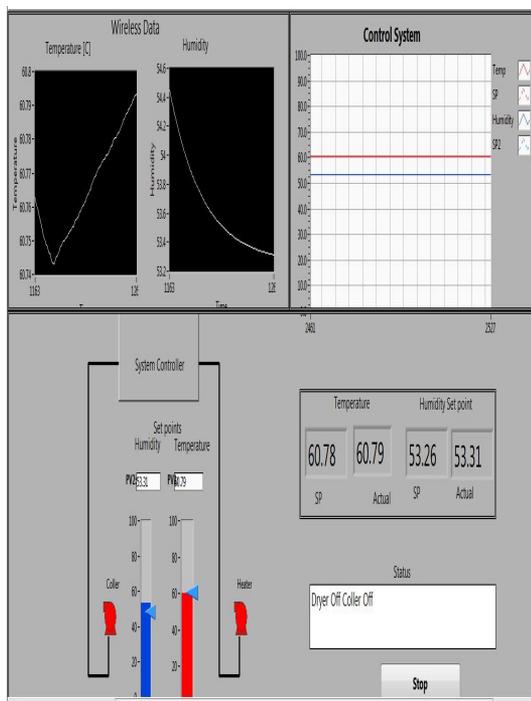


Fig . Errors in the Y coordinates

A component in the fix system was subjected to a cautiously test, with the aim to verify the limits of the proposed approach. Several tests were performed together with the fingerprinting approach. Figs. show the errors between the real X and Y coordinates and those calculate by the fixed system, in 50 different location inside the greenhouse. As it is shown, the maximum error is confined to 0.5 m, which is acceptable for this application. Higher accuracy would require more sophisticated and expensive approaches without introducing real advantages. The measurements have shown the same precision under both dry and humid conditions in the greenhouse, this way display that air humidity does not affect the RSSI. Alternately, if the irrigation plant is turned on, the rain can produce irregular errors.

B.Integration And Usability Test

The consolidation test consisted mainly of some joint communication and control tests. The SCADA system was capable to read from and send command to some devices through the hybrid communication network. The test was bound only to the use of the main fuctionalities available at the Application Layer since its aim was only to verify the possibility of consolidating all components in the greenhouse application.

With regard to the GUI, two different approaches were tested. The first is a traditional keyboard and LCD monitor, and the second approach is based on a touchscreen monitor. Even if the first approach allowed one to define a more detailed interface, the second approach has shown greater availableness, the possibility for the farmer to interact directly with the application even through a simplified TS interface has shown to be very attractive.

6 CONCLUSION

The communication system used to monitoring and control of greenhouses. This system is characterized by some interesting features, for example, the use of a hybrid wired/wireless communication infrastructure which simplifies the deployment of sensors and their orientation on the ground and makes the system highly variable. Moreover, besides using two different networks (wired and wireless), the Application Level based on SDS provides a merged service set which can be used by the application processes without the need to categorise if a policy fit to the wired or wireless network. This mode, all devices are managed as if they fit to a single network. This necessary the implementation of a proper bridge that is able to hide the differences between the two protocols and make the system uniform. The system has also been curtly tested in an open-air field, still showing its flexibility and its skill to operate in different environments.

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