M I S : Mobile Intelligent System

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Abstract

The work presented concerns the design, specification and realization of a wireless sensor network node.In this paper, we introduces the original Mobile Intelligent System (MIS). The system is based on an embedded Co-Design FPGA architecture, including a microprocessor core and several dedicated IP (Intellectual Property). Real tests in network sensor of variable topology have been carried out and have permitted working node validation.The system enables the collect of environmental data using mobile sensors in order to detect any important variations for triggering alarms.In the sake of improving the processing time, the paper presents also a new approach of routing protocols by material acceleration.

Key words: *Information systems and embedded application, Intelligent sensors, wireless sensor networks, system on Silicium (SoC and SoPC), Co design, Bloc IP (Intellectual Property) and FPGA.*

1. Introduction

In recent years, tremendous technological advances have been made in the areas of wireless ad hoc and sensor networks. Such networks have a significant impact on a variety of applications spanning scientific, military, medical, industrial, office, home, and personal domains.

The sensors become necessary elements in all systems where information resulting from the external environment is necessary to evaluate and act. To have an exact and complete knowledge on the subject requires the deployment of several sensors, and possibly, to combine all retrieved information to have a better adjustment of each parameter's sensor.

A sensor network is composed of a large number of units called nodes. Each node is composed principally of one or several sensors, a processing unit and a module of communication, etc... These nodes communicate between each other according to the network topology and the existence or not of an infrastructure (access points) to forward the information to a control unit outside the zone of measure. All these features enable us to imagine an adaptive complex system built around several sensors in a wireless communication system. An original system has been designed and realized named **MIS (Mobile Intelligent System)** project, which allows integrating three main functions: acquisition, processing and routing of information around embedded architecture like FPGA.

In this paper, the architecture of MIS is presented, featuring motion detection, object recognition, video compression and transmission by routing over low data rate wireless networks. A new approach for improving the processing time in protocols of routing by material acceleration; and invention of an ad-hoc mobile router are also presented [5].

This paper is organized in four sections: The first section is reserved for a general introduction. The second section presents some applications on network of wireless sensors. Section 3 focuses on the functional architecture of MIS platform and its units. The last section is reserved to the implementation and the new experimental results of the beacon. The paper ends with a conclusion and some perspectives.

2. State of the Art on sensors networks

Some laboratories have recently implemented practical achievements upon network sensors. The following applications are given as examples:

- University of Berkeley, INTEL and DARPA (USA)

A network made of up to 800 different sensors was realized for military applications. Each element of the network consists of a temperature sensor, a light sensor, a battery, a T1000-10kb/s RF module and an ATMEL RISC 8-bit microprocessor (with 4MHz and RTOS (TinyOs)) [1].

- University of Pennsylvania (USA)

A system composed of sensor networks is designed in

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order to control the quality of water [2].

- Crowsbow Technology company (USA)

Crowsbow MICA sensors create a wireless sensor network for the supervision and detection of several targets. The MICA architecture can detect vibrations, acoustic noises, light and temperature. Moreover, they are equipped with an interface which authorizes the connection of chemical and biological sensors [3].

- University of California, Berkeley (USA)

The scientific and engineering goal of the Smart Dust project is to build a complete, complex system in a tiny volume using state-of-the art technologies (as opposed to futuristic technologies), which will require evolutionary and revolutionary advances in integration, miniaturization, and energy management [4].

This project was about building a self-contained, millimeter-scale sensing and communication platform for a massively distributed sensor network. This device is around the size of a grain of sand and contains sensors, computational ability, bi-directional wireless communications, and a power supply, while being inexpensive enough to be deployed by hundreds.

3. MIS platform

In this section, we will present the MIS project previously introduced in [5-7].

3.1 MIS presentation

MIS (Mobile Intelligent System) is a platform of prototyping of intelligent wireless sensors elaborated within Wireless Sensor Networks (WSN) group of the Laboratory Electronic and Communication (LEC) for topological applications of networks of communicating objects. This platform is based with various sensors (CO, resistive tape recorder...), of a routing and treatment unit, a module of wireless radio communication using standard BLUETOOTH or WIFI and a routing and treatment unit based on a microprocessor (IP software).

3.2 MIS applications

One of the main applications is the construction of mobile autonomous units' network capable of moving in unknown environnement, inaccessible, hostile for human being or in risk areas (fire, radiation, earthquake...) in order to optimize the human assistance. The aim is to provide ground information to establish a strategy of evolution according to the wished purpose. For example, we can locate victims during the rescue operations. This is possible thanks to small mobiles capable of infiltrating through rubble or others explore the watery funds, another application, and not the slightest, is the military exploitation. In this context, the use of sensors' networks allows the surveillance of the perimeters, to assist air or ground attacks and to lead operations of espionage. For that purpose, no element has to be indispensable for the functioning of the network. Such an Ad hoc architecture can maintain the network in activity after the loss of one or several elements and requires a routing module.

3.3 MIS Architecture

The functional architecture and the experimental platform MIS, is built upon the kit of development ALTERA SOPC (System One Programmable Chip), it is composed essentially by 4 units (figure 1): an acquisition unit, a treatment unit, a routing unit and a radio interface unit.

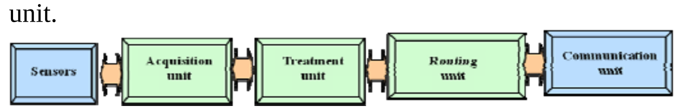

Figure 1 : MIS architecture

The detailed architecture of the designed and produced beacon is given below (fig 2).

It is articulated around the Nios II processor. Several interfaces are used in order to connect the peripherals to processor (SPI, UART, Bus Avalon, PIO...).

The system is also composed of different sensors allowing the data acquisition, and the generation of the numerical signals. These signals are treated by target card ALTERA cyclone. After treatment, the control signals are routed towards a central station using a routing protocol.

4. Implementation and new results

In the next subsections, we are going in this section to describe mainly our contribution as the "MIS experimental platform'', subject of this paper. The others are actually in progress. (Fig.2).

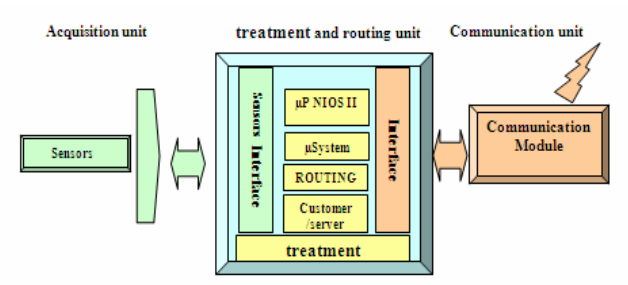

Figure 2 : MIS experimental platform

MIS experimental platform includes essentially :

- A sensor signal acquisition unit;
- A processing unit;
- A wireless network interface unit;
- A routing unit.

4.1 Architecture

The experimental prototype of the wireless intelligent beacon, MIS, has been designed around a Hardware/Software platform; the ALTERA Cyclone development kit.
A sensor unit allows acquiring environmental data such as temperature, magnetic field, pressure… from the processing unit.

After the processing phase, measures are sent (if alarm is generated) to a distant host via the wireless communication interface through the wireless network realized by the entire beacon. In order to achieve this nominal operation, a hardware and software development has been performed.

4.2 Hardware development

The hardware development consists of designing and interfacing all units realizing the acquisition, the routing, the computational processing and the wireless communication.

Sensor unit

The sensor unit is based on the use of three different sensors:

- a thermo-resistive sensor which gives analog thermal measures
- a HMC1002 sensor (magneto-resistive sensor) that allows to determine the change in the earth's magnetic field due to the presence of a ferromagnetic object or position within earth's magnetic field. This sensor delivers analog voltages as a function of the two-axis (x,y) of the incident magnetic field.
- a pressure sensor (MPX2100AP) to measure atmospheric pressure

Before the digital conversion by an AD7810 (10-bit Analog to Digital Converter, 100kSPS, with SPI interface), all the analog signals are multiplexed. The ADC is moreover under the control of the processing unit.

Camera unit

The general structure of the camera interface is presented by the following synoptic (figure 3):

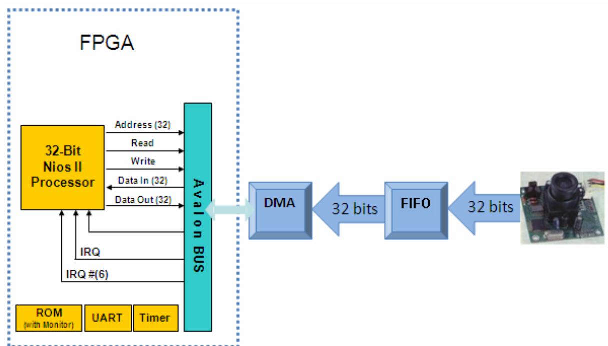

Figure 3: Synoptic of the camera interface

The camera provides in output 8-Bits video data, a clock signal with 14.318 MHz frequency and synchronization signals: line synchronization (LDV: Line Data Valid) and frame synchronization (FDV: Frame Data Valid). The camera interface enables to send the acquired video data and other control signals towards the Avalon bus.
This interface consists of three modules. The camera control module allows sending the acquired video data towards the FIFO module by using a 32-bit word. Indeed, in order of using the whole 32-bit bus size, each four 8-bit data pixels must be processed at 32-bit word.

The FIFO allows memorizing image line (640 pixels). It is like a buffer between the data writing and reading. The writing on the FIFO is synchronized with the camera clock. On the other hand, the reading is synchronized with the system clock (50 MHz). Indeed, it is necessary that the reading of the FIFO data towards the SDRAM is quite fast to follow the camera stream.

The third module is the DMA that allows the data transfer from the FIFO towards the SDRAM through the

Avalon bus by sending «master_w», «master_addrw» and «master_wrdata» signals. The cycle of writing operates until the Avalon bus sends «master_waitreq» signal.

The entire interface is described in VHDL. It defines the interconnections of side camera as well as the connection signals with the Avalon bus. For compilation and synthesis, we have used the Altera Quartus tool.

Routing unit

Implementation of OLSR on MERITE, based on platforms ALTERA (System One Programmable Chip), can be done in two different ways, as illustrated in figure 4, either directly into software, or hybride: software part is C language and material acceleration implemented using hardware description language (VHDL).

After a first study on PC type architectures, a version of only software OLSR on FPGA is implemented to test at first the correspondence of the results, and then understand in a second time the optimizations to be made to respond the criterion of consumption and speed of execution, (see figure 4).

OLSR was implemented into FPGA development Kit integrating a software 32-bit processor (IP) of the NIOS II type. This kit has the advantage of integrating an Ethernet interface with a TCP/IP API, as illustrated in figure 5 and 6. So, a wired network of cards all equipped with OLSR can be easily realized. Before integrating the OLSR, we have evaluated the size of the required memory (RAM, FLASH) and have taken into account the weak of the memory use.

We have used a NIOS II/Cyclone platform with the environment Quartus/SOPC builder on a computer station. The Quartus software (ALTERA) enabled at the same

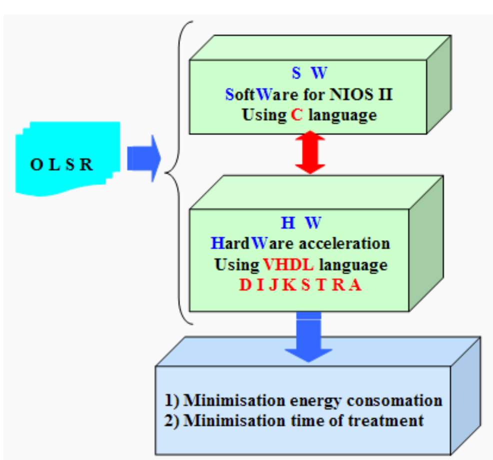

Figure 4 : The implementation of the OLSR on a Co-design platform.

time to represent material architecture and the transfer towards a SOPC. SOPC-Builder integrated in QUARTUS enabled us to configure the architecture of processor NIOS II and to define the library of programs necessary for piloting its interfaces. The OLSR protocol does not route the data, it just updates the routing table of the IP stack on a kernel of the operating system.

There is already several embedded distributions based on Linux whose the majority is composed of open source projects: PeeWee Linux, RTLinux, RTAI, TUXIA, Red Hat Embedded Linux, µClinux, Embedix. The integration of OLSR in the platform has been finalized and has been made possible by using in addition an operating system of µClinux type, which has several advantages over its competitors as compatibility of API's programming with the standard Linux systems. It also has all TCP/IP network functions, available on the Linux kernel and supported by the ALTERA card.

Figure 6 shows the architecture of the Altera card and the positions of our OLSR related to other components (tcp, udp ...).

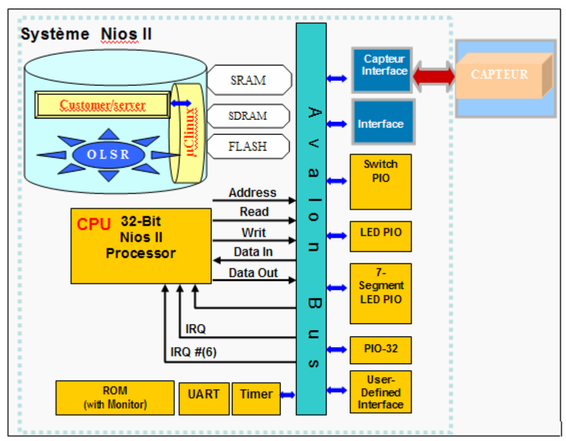

Figure 5: Synoptic of the System SoPC NIOS II for the acquisition and the routing of temperature

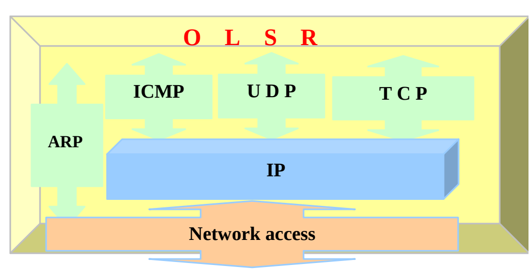

Figure 6: TCP/IP network functions of ALTERA card used by OLSR.

To check the possibility of routing the data collected by various sensors, a network topology of several nodes is selected, figure 7.

The protocol was launched on two units being in the extremities of our network. These machines were not able to be identified, because they have no MPR... The table of routing contains only the address of our network and the local loop. The data is not transmitted to the distant unit.

The execution of the OLSR on the units which are between distant nodes, the various MPR, and the neighbors of the first one and the second jump are mentioned. This information is updated when any changes are detected in the network. The data is transmitted to the distant unit according to the shortest path.

Optimization routing unit

In this section we present the optimization of routing unit and we study the performance differences between the VHDL program on FPGA and a C program (running on µClinux) running the same algorithm. We use one of the main constituents of the OLSR that is the algorithm of Dijikstra (figure 8).

A version of Dijikstra's shortest path algorithm was designed using VHDL. The design was targeted for Altera's FPGA device family with the Quartus design software. To compare the performance of an FPGA Dijisktra's algorithm, an identical algorithm was coded in C.

The speedup factor in favor of the FPGA depends on the number of network nodes (network sizes). Whereas the average execution time of the Dijikstra coded in C VHDL was faster than a Dijikstra coded in C (running on µClinux). See figure 8 and table 2.

This can be attributed to the following factors: multiple assignments to variables are executed concurrently, multiple arithmetic operations, including comparisons, are executed in parallel and the data structures and tables are implemented in the internal memory blocks.

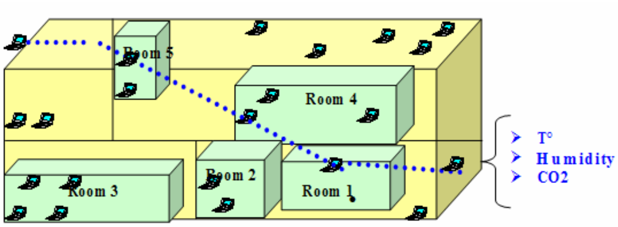

Figure 7: Logic network topology

Number nodes	Execution time (µs) Dijkstra's :		Speedup factor
	VHDL on FPGA	C on FPGA	
10	10	259	25,9
20	13	474	36,46
30	17	832	48,94
40	21	1104	52,57
50	25	1456	58,24
100	35	2337	66,77
1000	57	12987	227,84

Table 2: Performance Dijisktra's algorithm

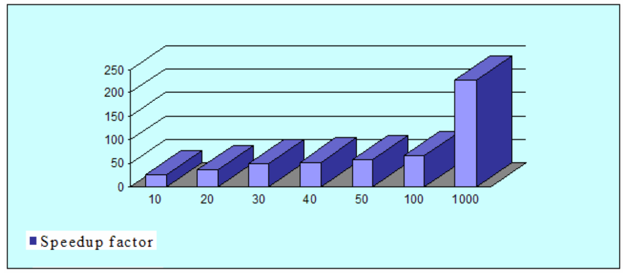

Figure 8: Speedup factor

Conclusion

In this paper, we have introduced the architecture of an intelligent beacon for wireless sensor networks and its first implementation on the MERITE platform. This beacon may acquire environmental data of the environment and detect possible defaults (great variations). When some alarm is triggered, data are sent on a wireless network such as Bluetooth.

This work presents also a new approach for improving the processing time of routing protocols by material acceleration. It has allowed huge progress of MERITE and the invention of an AD HOC mobile router.

However, many improvement works are still necessary to strengthen the present system. They concern in particular the minimization of the energy consumption and the speed of treatment and data transmission as well as the transportability of the system towards other platforms...
The interest of such a work has a big impact for the applications related to the networks of wireless mobile sensors, in particular those dedicated to the military domain.

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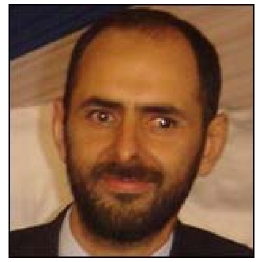

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