Poster Abstract: Wake-up architecture for Wireless sensor nodes based on ultra low power FPGA.

V. Rosello, J. Portilla, T. Riesgo
Centro de Electronica Industrial, Universidad Politecnica de Madrid
{victor.rosello, jorge.portilla, teresa.riesgo}@upm.es

Abstract— **In this work a novel wake-up architecture for wireless sensor nodes based on ultra low power FPGA is presented. A simple wake up messaging mechanism for data gathering applications is proposed. The main goal of this work is to evaluate the utilization of low power configurable devices to take advantage of their speed, flexibility and low power consumption compared with traditional approaches, based on ASICs or microcontrollers, for frame decoding and data control. A test bed based on infrared communications has been built to validate the messaging mechanism and the processing architecture.**

I. Introduction

Energy usage in wireless sensor nodes is the main barrier to get fully unattended or even perpetual wireless sensor networks deployments. In order to get more energy efficient wireless sensor nodes a lot of research activities are being carried out related with all the steps of the system design, from energy sources to software development. In this work we focus on the communication layer because usually a big amount of energy is wasted listening the radio channel while there are no active communications.

In order to eliminate the waste of energy in main communications a low power wake up device can be used to activate the node only when needed, remaining in low power mode most of the time. The main requirements of this wake up devices were defined in [1]: ultra low power consumption, false wake ups should be avoided, wake-up calls should not be lost and fast wake-up call detection, in order to not impact in the overall performance of the node and the network.

The basic architecture of nodes with wake-up capabilities is a regular node with a custom wake-up transceiver (or just a receiver) for wake-up communications. To process the information of the wake-up messages normally the main processing unit of the node (typically a low power microcontroller) is used.

In this work, a new approach is proposed, based in an ultra low power FPGA as the processing unit. The use of these devices against the implementation using processors permits to reduce the wake-up time and allows incrementing the baud rate of the wake-up channel which helps to reduce the latency of the network.

The implementation presented in this work uses infrared communications. The usage of this kind of communications permits a cheap and easy way to validate the proposed wake-up message mechanism designed. This kind of communications based on commercial infrared components present important drawbacks as the low baud rate and high power consumption. These factors make them hard to be used in real applications. However, for proof of concept they are quite suitable.

II. Node Architecture

The architecture of the wireless sensor node used in this work is shown in Figure 1.

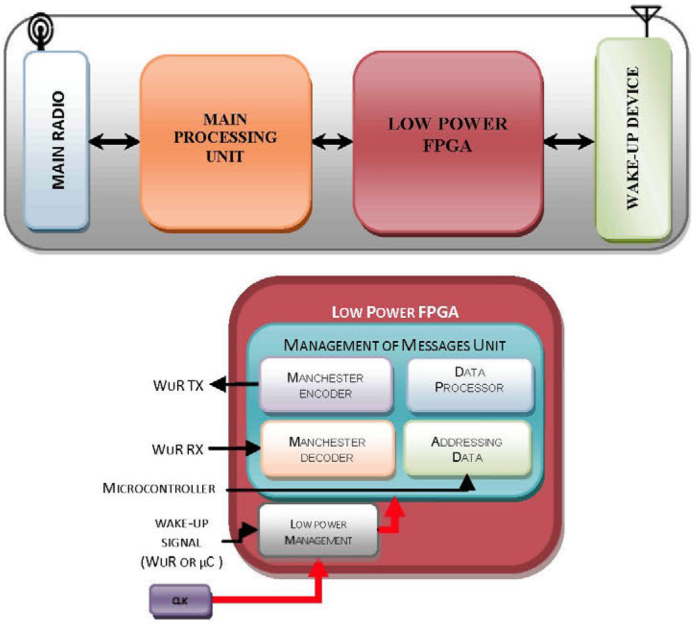

Figure 1. Node architecture.

Main characteristic are:

- Main radio channel: commercial chip based on ZigBee, working on the 2.4 GHz band.
- Microcontroller: low power microcontroller MSP430 FG438 from Texas Instruments, used for data processing.
- Ultra low power FPGA: Igloo AGL250V5 from ACTEL (250000 equivalent gates). Used to control the wake-up communications. The wake up processing architecture has been already presented in [2].
- Wake-up Device: based on an infrared LED for transmission and a commercial infrared receiver for the reception.

In order to avoid problems caused by use separate channels with different ranges the main radio channel range is limited to be under the wake-up communications range. The route between nodes and addressing assignment relays on the ZigBee communication channel. In this way asymmetrical routes are avoided and it permits to simplify the wake-up processing unit which helps to reduce the power consumption of the processing unit.

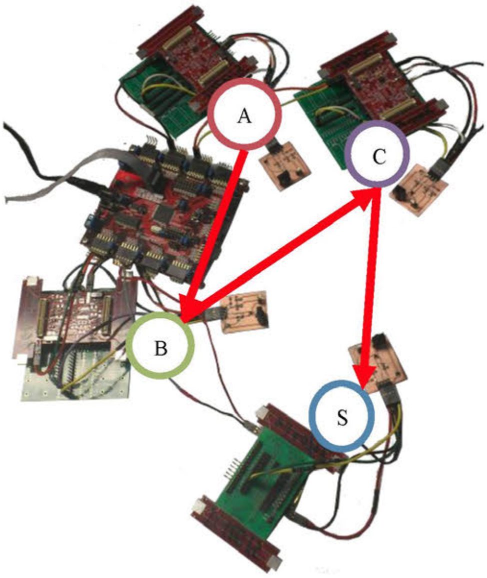

Figure 2. Testbed sceneraio

III. Wake-up Mechanism

The mechanism proposed in this work has been designed for data gathering applications only, in order to reduce the complexity of the wake-up messaging. In this kind of applications a sensor node measures periodically their environment and sends the data to a concentrator node, named in this work sink. The communications between distant nodes are not used. With the characteristic of this scenario where only unidirectional communications are used (from a sensor node to the sink) the proposed mechanism only needs 2 types of messages to have a functional application. These messages are:

- R2SINK (Route to Sink): this message is sent to wake up the next node in the path to the sink.
- NWKRroute (Network reroute): this message is used to wake up all the nodes in the network when a route error is detected. When a node receives an NWKRroute message it broadcast the message till reach the all nodes in the network.

A. Wake-up channel characteristics

The transmission is modulated using Manchester code. This kind of codifications permits to avoid the use of preamble synchronization using very few resources of the FPGA.

The bit time is 300 µs and the modulating frequency of the wake-up channel is 55 KHz.

IV. Testbed

The test bed used is based on 4 wireless sensor nodes with the infrared transceiver attached to each one and an external microcontroller that acts as data logger for the state of the processing units of the nodes. The routings tables of the wake up processing units have been initialized in order to have the route shown in Figure 2.

A. Experimental results

Comparison about the implementation of the processing unit using the microcontroller and the FPGA has been made, and a summary of the results are presented in Table I.

TABLE I: Wake-up processing unit Implementation Results

		t_{wakeup} (ns)	t_{start} (µs)	t_{sleep} (µs)	I_{on}(mA)	I_{sleep} (mA)
MSP	Max	--	17,22	38,79	3,2308	2,06
	Min	--	4,2	37,5	2,6194	1,47
IGLOO	Max	370	56,8	0,43	5,1	4,09
	Min	386.5	56	0,41	1,9	1,09

In Figure 3. are shown some experimental results for the message mechanism, in (a) a R2SINK message sent from A to B is shown and the original message and the response are shown. In (b) an NWKRroute broadcast is shown, the Node oA (out of figure) sent the first message that travel through the rest of nodes in the network.

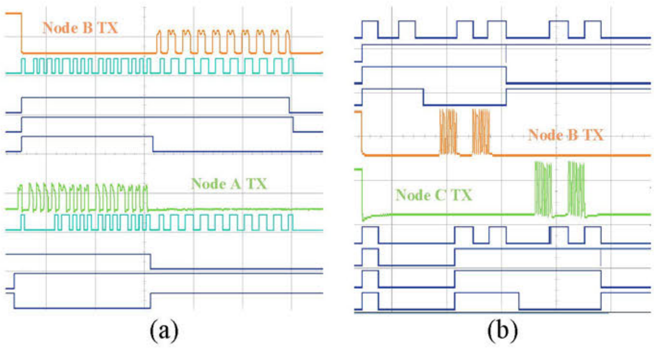

Figure 3. Experimental results (a) R2SINK (b)NWKRroute

V. Conclusion

As it can be seen in Table I, power consumptions are in the same range in FPGA and in microcontroller, taking into account that the FPGA works faster than necessary (11.0592 MHz) and a bigger device than necessary, the design fits on a AGL20 (20000 equivalent gates), important reduction can be achieved in the FPGA implementation.

A simple mechanism for nodes with wake-up capabilities has been tested in data gathering applications.

VI. References

[1] L. Gu, and J. A. Stankovic. "Radio-Triggered Wake-Up for Wireless Sensor Networks". Real Time Systems, vol. 29, pp. 157-182, 2005.

[2] V. Rosello, J. Portilla, T. Riesgo. "Ultra Low Power FPGA-Based Architecture for Wake-up Radio in Wireless Sensor Networks" in Proceedings of the Industrial Electronics Conference (IECON'11), November 2011, Melbourne, Australia.