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DEVELOPMENT OF A RELIABLE WIRELESS GNSS SENSOR NETWORK

Fabio Casciati¹, Sara Casciati², ZhiCong Chen³, Lucia Faravelli¹, Michele Vece¹

¹ DICAR, University of Pavia, Via Ferrata 3, 27100 Pavia, Italy.

² DICAR, School of Architecture, University of Catania at Siracusa,
P.za Federico di Svevia, 96100 Siracusa, Italy

³ Institute of Micro/Nano Devices and Solar Cell, College of Physics and Information Engineering,
Fuzhou University, QiShan Campus, Fuzhou 350108, China

fabio@dipmec.unipv.it

ABSTRACT

To localize, track and trace critical assets and first responders for remote emergency management are primary needs after a catastrophic event. In disaster areas, however, it is likely that the existing terrestrial communication network and the power grid will be cut off. Therefore, a reliable asset tracking system should be independent of those terrestrial networks, especially in terms of communication. This paper explores the development of a reliable low power local wireless communication network for portable GNSS-based positioning sensors and a centralized recording unit, as part of the independent communication network. The wireless sensors network is based on the ZigBee standard protocol and the IEEE802.15.4 compliant transceiver CC2530 from Texas Instrument. The network features low cost, low power, mesh topology, high reliability and high security.

KEYWORDS: *Critical Asset Tracking; GNSS sensor, Wireless sensor network, ZigBee.*

1 INTRODUCTION

An ongoing research effort aims at improving the state of the art related to the exploitation of the potential offered by the satellite network. Based on precise positioning and timing system, coordination and operation in emergency scenarios would find a significant help in the transfer of information coming from a networks of units reading the Global Navigation Satellite System (GNSS).

It is well known [1-3] that for structures requiring the accuracy of centimetres, global positioning systems (GPS) offer a valid solution because the technology covers a large area and it is suitable for the monitoring of constructions characterized by a large own period.

One feature of GPS units to be placed across the area under inspection is to rely on internet for transferring the local information to a recording nucleus. However, in any disaster areas, it is quite likely that the existing terrestrial communication network and power grid will be cut off after the catastrophic event. Therefore, a reliable asset tracking system should be independent of those terrestrial networks, especially in terms of communication. This paper explores the development of a reliable low power local wireless communication network for portable GNSS based positioning sensors and a centralized recording unit, as part of the independent communication network.

Actually, the research activity reported in this paper is devoted to the implementation of a basic component within the European Union FP7 project named "Satellite Based Asset Tracking for Supporting Emergency Management in Crisis Operations (Spartacus)": a local low power wireless communication network. The Spartacus project aims to develop Galileo-ready satellite-based applications to address three main societal needs, i.e., (1) Track, trace, and localize critical transport

assets especially in times of crisis and in case of major failure of existing networks (communications and power); (2) Track the flow of relief support goods from the sending side to the receiving side; (3) Support coordination and ensure the safety of first responders in disaster management operations. One major component of the project is to develop a portal, mobile and rapid-deployment communication infrastructure on site by integrating terrestrial wireless access technologies with satellite backhauling technologies, in which the low power local communication network is required to connect GNSS based tracking units and a centralized collecting unit.

In terms of position tracking of critical assets, in addition to the basic position of the whole transportation vehicles, the high-accuracy displacement monitoring of their key mechanical components is important for the health monitoring to ensure the integrity and thus safety. Since many GNSS based tracking units are expected to be distributed in the transportation vehicle, the conventional cabling method suffers problems, such as inflexible installation and negative impact on the vehicle structure, which suggests the adaption of a local wireless communication network [4-6]. Furthermore, in terms of position tracking of first responders and other onsite users, a wireless solution is also required.

The local wireless communication network should operate long enough to support the first 24 hours after an emergency, without connection to the grid. Therefore, it should features low power.

Furthermore, the network should have encryption function to ensure a high security. These requirement can be well met by the ZigBee standard network, which is a low-cost, low-power, wireless mesh network standard. ZigBee operates in the industrial, scientific and medical (ISM) license-free radio bands: 868 MHz in Europe, 915 MHz in the USA and Australia and 2.4 GHz in most jurisdictions worldwide. Data transmission rates vary from 20 kilobits/second in the 868 MHz frequency band to 250 kilobits/second in the 2.4 GHz frequency band. ZigBee networks are secured by 128 bit symmetric encryption keys. Its transmission distances range from 10 to 100 meters line-of-sight, depending on power output and environmental characteristics. In order to have a longer range, an external radio power amplifier can be adopted with ZigBee compliant transceiver.

There are many ZigBee compliant transceivers and protocol stacks offered by different companies, which can implement the ZigBee network. In this paper, the CC2530 and the Z-Stack are adopted.

2 SYSTEM ARCHITECTURE

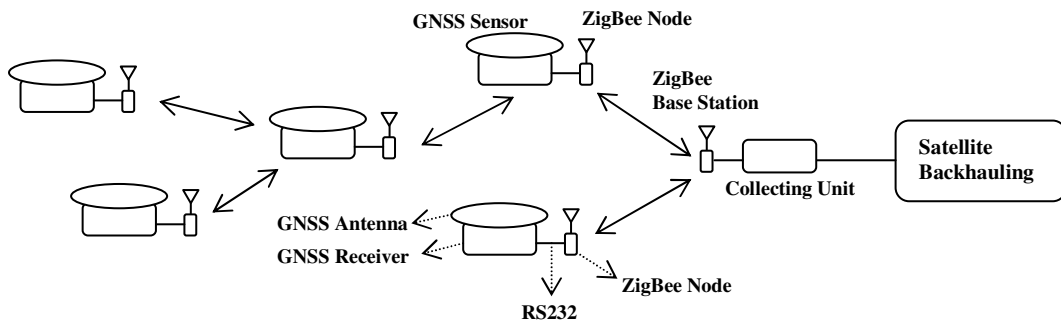


Figure 1: Wireless GNSS sensors network

As shown in Figure 1, the local wireless GNSS sensors network consists of several GNSS sensors integrated with a ZigBee node through RS232 serial port, and a collecting unit integrated with a ZigBee base station also through RS232 serial port. The GNSS sensors acquire their positions from the GNSS satellites signal periodically and send the position data to the centralized collecting unit through the multi-hop ZigBee mesh network. In order to pass the collected data to the remote centre, the collecting unit is connected to the internet through a satellite backhauling device. In this way, a local existing terrestrial communication infrastructure can be avoided.

3 DEVELOPMENT ENVIRONMENT OF THE TI CC2530 BASED ZIGBEE NETWORK

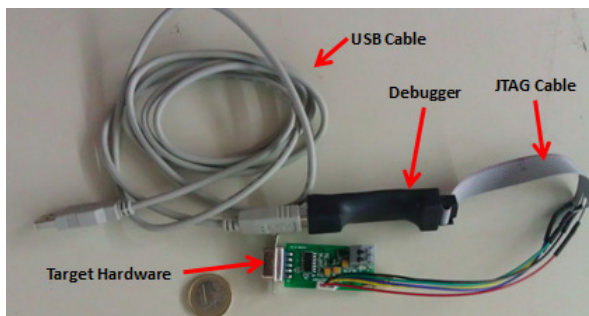
The CC2530 is a true system-on-chip (SoC) solution for IEEE 802.15.4, Zigbee and RF4CE applications, from Texas Instrument. It enables robust network nodes to be built with very low total bill-of-material costs. The CC2530 combines the excellent performance of a leading RF transceiver with an industry-standard enhanced 8051 MCU, in-system programmable flash memory, 8-KB RAM, and many other powerful features. In order to develop the CC2530-based ZigBee device, there are many software tools involved, as shown in Fig.2. Firstly, an integrated development environment (IDE) is needed to program and compile the firmware code for the 8051 microcontroller core integrated in the CC2530 transceiver. The adopted and compatible IDE software is IAR Embedded Workbench 8051. Secondly, a Zigbee protocol stack is needed, which is provided for free by Texas Instrument and named Z-Stack™. It is an open source stack. The latest version is ZStack-CC2530-2.5.1a. The developer just needs to design the application program based on the stack. Lastly, Texas Instrument also provides two other software tools for free to facilitate the debug and testing of ZigBee transceiver and wireless network, including SmartRF Studio 7 and Packet Sniffer.



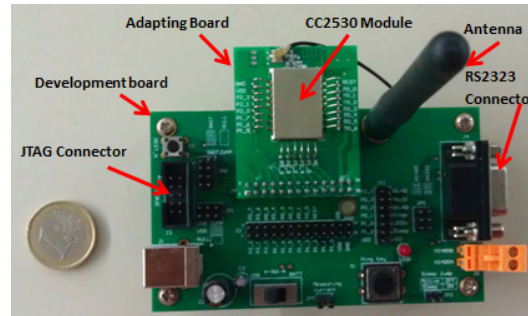
(1) IAR EW8051

(2) SmartRF Studio 7

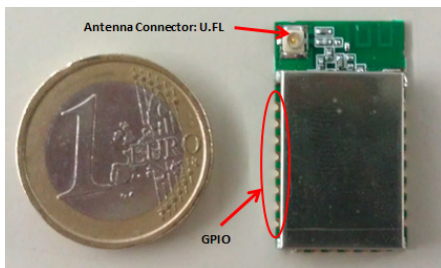
(3) Packet Sniffer



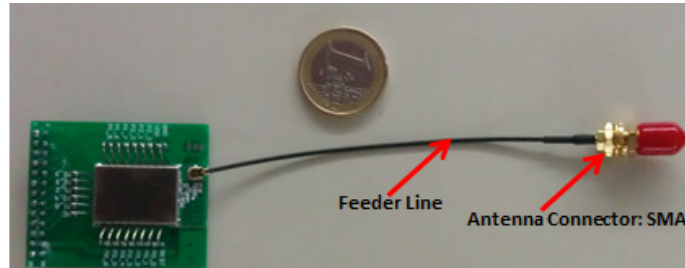
(3) Debugger



(4) Development board



(5) CC2530 High Power Module



(6) CC2530 high power module mounted on adapting board

Figure 2: Development Environment of the CC2530 based ZigBee Network

In addition to the software tools mentioned above, some hardware tools are needed to construct the whole development environment for the CC2530-based ZigBee-Serial Port adapter. The relevant hardware tools include debugger, development board, transceiver module and its adapting board, as shown in Figure 2. The debugger is used to download and debug the firmware for the CC2530 8051 microcontroller core. The development board is used to facility the access of the resource of the CC2530 transceiver module. The transceiver module integrates a CC2530 chip and its peripheral passive components pin out its GPIO (general purpose input and output) and power supply ports on a small PCB board.

4 HARDWARE OF THE ZIGBEE NODE AND BASE STATION

As shown in Figure 3, the ZigBee node is a ZigBee to RS232 adapter, simply consisting of a CC2530 module, an antenna, an UART to RS232 converter , a DB9 serial port connector, a 5V power supply connector and a JTAG interface for downloading and debugging the firmware.

As shown in Figure 4, the ZigBee base station is a ZigBee to USB (Virtual RS232) adapter, simply consisting of a CC2530 module, an antenna, an UART to USB bridge, an USB connector and a JTAG interface for downloading and debugging the firmware.

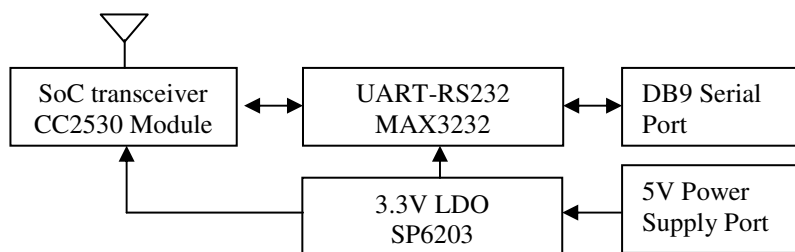
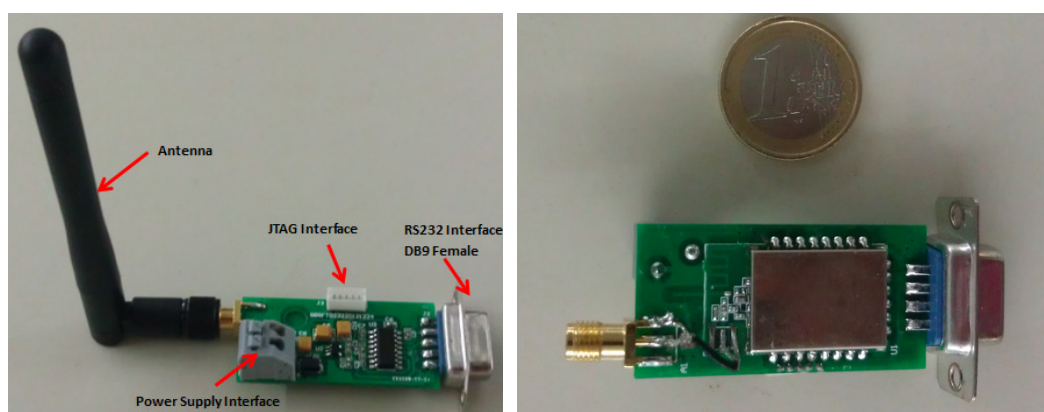


Figure 3: The ZigBee node hardware - Top view (left), bottom view (right), and block diagram

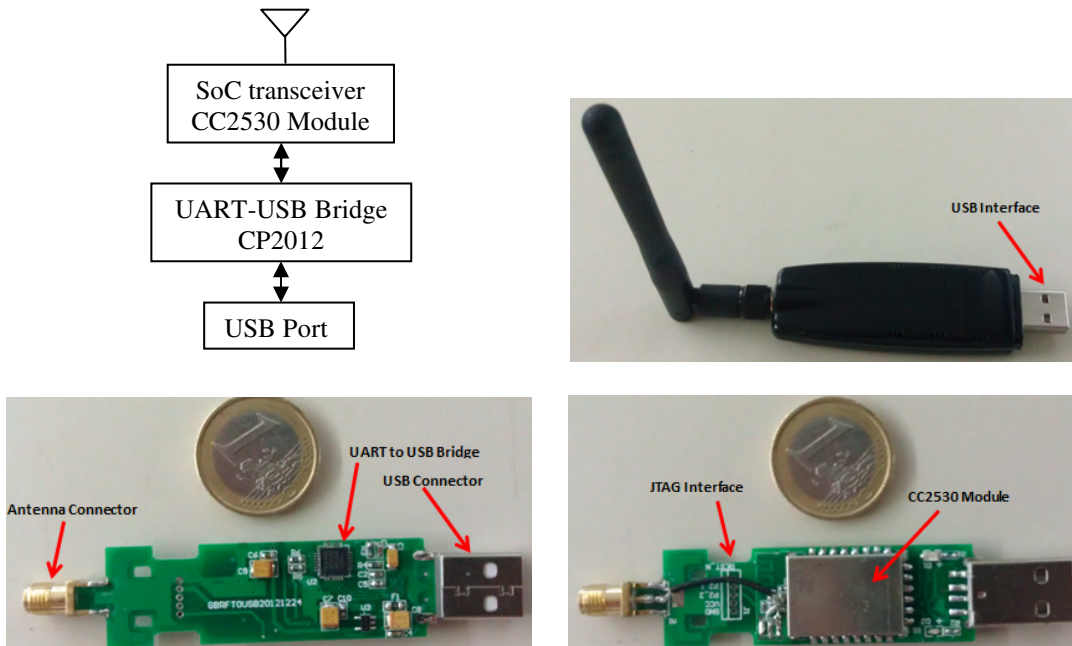


Figure 4: The ZigBee base station hardware - Block diagram, package, bottom view and top view

5 FIRMWARE OF THE ZIGBEE NODE AND BASE STATION

The firmware application (named SerialApp, as shown in Figure 5) of the ZigBee nodes and the base station is built on the ZigBee protocol stack Z-Stack (Version ZStack-CC2530-2.5.1a) and implements a transparent data transfer between the serial port and the ZigBee stack. When a data packet is received from the air (ZigBee stack), the SerialApp will pass it to the serial port. When a data stream is sent to the serial port, the SerialApp will pass it to the air. Since the data over the air is based on packet and the packet length is limited, the data stream from serial port may need to be fragmented. The SerialApp adopts software flow control to frame the data stream from serial port into packets: the received serial data will be processed when the data number or the idle time exceeds a predefined threshold.

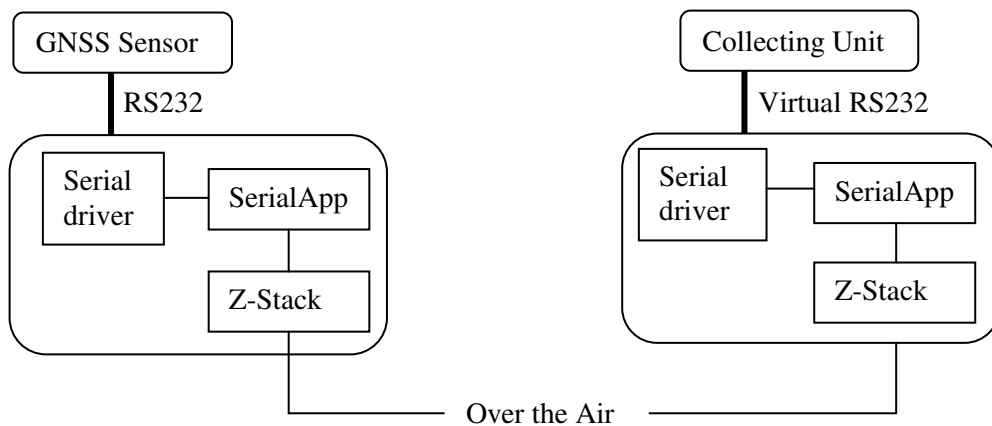


Figure 5: Block diagram of the firmware application of the ZigBee node and base station

For the reliability of the wireless data transfer, in addition to the single-hop acknowledgement, the Z-stack offer end to end acknowledgement function to enable the sending device get confirmation that a data packet has been delivered to its destination device. Since many GNSS sensors send their data to the centralized collecting unit simultaneously and the data of one GNSS sample is long and should be divided into more than one packet, the integrity of GNSS sample data many be damaged. To avoid this problem, Z-Stack's message fragmentation function can be used, which is a process where a large message is broken down and transmitted as smaller fragments. The fragments of the larger message are then reassembled by the receiving device.

Through the about discussed techniques, the SerialApp can achieve a reliable transparent data transfer between GNSS sensors and the collecting unit.

6 CONCLUSIONS

This paper presents a preliminary solution for the ZigBee-based low power wireless communication network of the European FP7 project Spartacus, adopting the CC2530 SoC transceiver and Z-Stack. The preliminary solution includes the hardware and basic firmware implementation of the standard ZigBee wireless sensors node, which was validated in laboratory environment.

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