Demo: INGA - An Inexpensive Node for General Applications

Felix Büsching
TU Braunschweig, IBR
Mühlenpfordtstr. 23,
38106 Braunschweig, Germany
buesching@ibr.cs.tu-bs.de

Ulf Kulau
TU Braunschweig, IBR
Mühlenpfordtstr. 23,
38106 Braunschweig, Germany
kulau@ibr.cs.tu-bs.de

Lars Wolf
TU Braunschweig, IBR
Mühlenpfordtstr. 23,
38106 Braunschweig, Germany
wolf@ibr.cs.tu-bs.de

Abstract

In this demo, we present some exemplary applications for INGA, a new and affordable wireless sensor node for general applications. INGA's hardware design is completely under open source license and it runs the open source operating system Contiki "out of the box". Several up-to-date sensors are included in the basic design and we developed it for research, medical applications and universal usage.

Categories and Subject Descriptors

C.3 [**Special-Purpose and Application-Based Systems**]: Microprocessor/microcomputer applications

General Terms

Design, Experimentation, Measurement

Keywords

Sensor Node, Wireless Sensor Network, Contiki, Hardware Platform, Gait Analysis

1 Introduction

For the design of INGA, our intention was to combine the benefits of well-known sensor nodes and minimize their disadvantages. In the GINSENG [3] project we learned that the well-known (MSP-430 based) TMote Sky is very limited in addressable memory as well as being old, slow and power consuming. In other projects (e.g. [2]) using the Atmel Raven, we discovered disadvantages as well: It is hard to handle (as it can only be programmed using a JTAG/ISP-adapter), it is comparatively big and only very limited sensors are present.

INGA's design is based on the Atmel AVR Raven Sensor Node and therefore is directly supported by Contiki [1] in its basic functionality. We integrated some more interesting sensors, like a 3-axis accelerometer, a 3-axis gyroscope and a pressure sensor. Moreover we implemented crucial functionality like a bootloader, online power-monitoring and expandable memory. INGA was designed to be built in a cheap way (two layer PCB, broad space between the PCB-tracks and drilling holes are comparatively wide) and can be soldered by (skilled) hand. Nevertheless, its dimensions are quite small (40 x 50 mm) and all relevant ports (JTAG, I^2C, SPI, GPIO, UART) are present on "normal" 2.54 mm (0.1 inch) multi-pin connectors. In figure 1 a prototype is shown. A fully equipped system provides the following functionality and the following parts are present:

- Atmel ATmega 1284P 8-bit pico-power RISC-MCU, 16 MHz, 128 kB Flash, 16 kB RAM, 4 kB EEPROM, 10-bit-ADC (6)
- Atmel AT86RF231 2.4 GHz IEEE802.15.4, ZigBee, 6LoWPAN Radio Transceiver with hardware AES support, attached to primary SPI (3)
- PCB High-Gain-Antenna (1) (we measured a coverage of 250 meter (line-of-sight) during an initial experiment)
- 16 MBit onBoard Flash Memory (7) and Micro SD-Card Slot (9) which can be completely switched off (no power consumption through data lines)
- Mini-USB-Connector (15) for UART-communication (RX/TX-LEDs (19)), programming (4) and LiPo-charging (13) (charging status indicated by LED)
- Voltage regulation (17) for attached (rechargeable) batteries, online current (2) and voltage (14) sensing
- Multiplexed 2nd SPI (8) and separate I^2C-bus with various sensors connected:
  - 3-axis accelerometer ADXL345 (5)
  - Pressure sensor BMP085 with integrated temperature sensor (10)
  - 3-axis gyroscope L3G4200D with integrated temperature sensor (11)
- User LEDs (16), user push-button (17), on/off-switch (12)

We estimate a total cost of 70 Euro (100 $) per piece with all functionalities present when producing 50 pieces in a factory. It is designed to be "lead-free" and for capacitors no "noble earths" (like tantalum) are needed. Of course it is also designed to be energy-saving.

2 Exemplary Applications

We intend to demonstrate the INGA node using several exemplary demo applications as outlined in the following.

2.1 Sensors for Movement and Position

INGA's sensor set mostly consists of sensors for movement or activity detection, because our project partners in-

SenSys'11, November 1–4, 2011, Seattle, WA, USA.
ACM 978-1-4503-0718-5/11/11

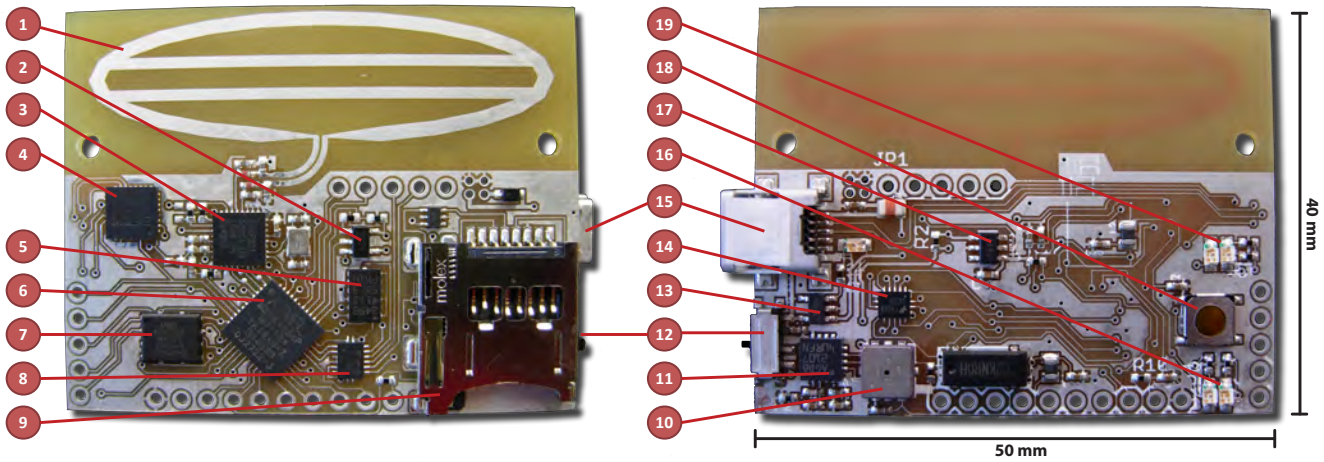

Figure 1. INGA's rear and front view with all relevant components marked

tend to use it for gait and activity monitoring of elderly persons. As an exemplary application we will show gathering and transmitting live data of every connected sensor to a remote PC. TCP/IPv6 will be used to transmit the data wirelessly over an IEEE802.15.4 connection. The measurements of the accelerometer, the gyroscope and the pressure sensor will be displayed in real time and can easily be affected by moving the sensor. There will also be a real time 3D-Visualization of the sensor node to demonstrate the potential of the sensors: You can twist and turn the sensor node and watch the live representation on a monitor.

2.2 Wireless Sensor Network

Another INGA node within the sensor network is used to display the altitude of the movable sensor using a LED-bargraph. This node is just listening to the transmitted data, computing the altitude from the pressure measurements and displaying it through attached LEDs, thus, when lifting the movable sensor, the other INGA reacts.

To show interoperability with other kinds of sensor nodes, an AVR Raven node is part of the wireless sensor network as well and is used to display various data, like temperature, on its LCD. We are using Contiki's μIPv6 implementation to set up the WSN, but any other communication stack will work as well.

2.3 Bootloader

A Bootloader was implemented to allow for (re-) programming of the node over a simple USB connection. Thus, no additional programmer is needed and ports previously reserved for JTAG or ISP may be used for different purposes. Flashing Contiki using the Bootloader takes less than 5 seconds and a toolchain to directly program a node through Eclipse using AVRDude is provided as well. Thus, nodes can easily be reprogrammed and no additional hardware is needed. This can also be the basis for flashing the nodes "over-the-air" in the future.

3 Conclusion

INGA was designed to be built in a cheap and easy way and will be published under open source license; everyone is free to use or modify the layout and to build the node. INGA's set of sensors is capable of monitoring movement, position and activity, which is very useful for medical applications. The same set of sensors can also be used in flight navigation (for example "quadrocopters") which might be another interesting area of application. Nevertheless, it is also useful for many other applications and research in the area of wireless sensor networks as it is easy to use and easy to expand. It directly runs Contiki, comes with a powerful radio transceiver and integrates in other wireless sensor networks. We have shown interoperability with the AVR Raven and we also managed to send packets between TMote Sky and INGA.

4 Resources

INGA's hardware design is completely under open source license. You are free to adapt or change anything you like. We provide schematics, EAGLE-files and Gerber-files in the download section of INGA's website. In addition all hardware drivers for Contiki will be provided in a SVN/GIT-repository and the demo programs can be found on the website as well:

`http://www.ibr.cs.tu-bs.de/projects/inga`

5 References

[1] A. Dunkels, B. Gronvall, and T. Voigt. Contiki - a lightweight and flexible operating system for tiny networked sensors. In *Proceedings of the 29th Annual IEEE International Conference on Local Computer Networks*, LCN '04, pages 455–462, Washington, DC, USA, 2004. IEEE Computer Society.

[2] M. Eichelberg, A. Hein, F. Büsching, and L. Wolf. The gal middleware platform for aal. In *e-Health Networking Applications and Services (Healthcom), 2010 12th IEEE International Conference on*, pages 1 –6, 2010.

[3] T. O'Donovan, J. Brown, U. Roedig, C. Sreenan, J. do O, A. Dunkels, A. Klein, J. Sa Silva, V. Vassiliou, and L. Wolf. Ginseng: Performance control in wireless sensor networks. In *Sensor Mesh and Ad Hoc Communications and Networks (SECON), 2010 7th Annual IEEE Communications Society Conference on*, pages 1 –3, june 2010.