Chapter 8

Conclusions

Like the legend of the phoenix
All ends with beginnings
What keeps the planet spinning
The force from the beginning

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This chapter covers a full review about the project. It is shown a general view of the implemented system together with the main taken decisions and carried out tasks. Most important conclusions are summarized and future lines are set.

The main goal of the project is to design and implement a node for the study of CWSNs. A demo application layer, also to be developed, must work integrated with an already implemented firmware. This employed firmware is able to give support to up to three transceivers sharing a single MiWi^{TM}stack. It focus on abstracting the developer and the application from the cognitive model and the direct hardware management.

The platform was developed responding to the requirements and a final demo let prove the right operation of the whole system. The whole system respond to a modular design widely adaptable over the range of WSNs applications. Main module is called cNGD. This main module posses different functionalities that implements a node platform, such as power supply, power control over modules, battery, expansion headers, RIs, serial interface, and a control MCU unit. RIs on board of cNGD offer communication over 434, 868, and 2400 MHz. RIs used for 434 and 868 MHz are ad-hoc designed RIs due to the lack of suitable size modules. This ad-hoc designed RIs are called μTrans 434/868 for 434/868 MHz respectively.

cNGD main module accepts expansion options over its headers, so-called shields, and for this project two shields were implemented. First shield gives chance to serial communication through an RS232 port. Second one is a suitable charger for the batteries. Shields allow developers to create new attachable functionalities and possibilities or give different capabilities to distinct reduced node groups of the total network. This helps to keep the downtrend on complexity, consumption, size and cost but not on performance.

The sort of device shown at this project features some novel properties with respect to other CWSN devices, such as its capability to communicate over three different ISM RF bands. The hardware fits the conditions and requirements of WSN environments. Low power consumption, size and cost limitations are taken into account in order to achieve real test-benching purposes, application development or even possible complete implementations.

In Section 1.2 takes place a fragmented set of subgoals is described, here they follow some conclusions obtenied throughout the achievement of these subgoals:

- A review all over the recent implementations related to the CWSN was made at Chapter 3. The FCD architecture is quite close to the one pursued so is taken as guide for the designing process. Used technology is evaluated and weaknesses detected, also minimal requirements are stated. Many decisions, such as a reconfiguration of the RIs, the design of suitable size RIs or the need for expansion options, were taken in order to face the design.

- The whole design is covered in Chapter 4. A modular design builds up the whole system. A total of three modules were designed, a main module, an ad-hoc RI and two expansion shields that provide extra functionalities. Battery options were studied resulting in a final option of 3-cells Ni-MH battery. Components were chosen and required functionalities assigned to different modules.

- At Chapter 5 is covered the hardware implementation. The PCB layouts were deployed and prototypes mounted. Size achieved is fair for research purposes. Node functionalities were checked and design validation with consequent corrections, these task were carried out during mounting making use of small pieces of software.

- Developed hardware have been submitted to several tests to check right performance of main capabilities. Hence, MCU capabilities, RI features, sleeping modes and current consumption have been proven. For this, tests included at the software have been generally used. In some cases the suffered slight adaptations.

- Software developed for hardware checkings, firmware adaptations, and final demo application is described in Chapter 6. Firmware has been slighly modified to exploit the hardware features. Final demo application proves right operation of CR functions applied to WSN communications.

After carrying out all the exposed tasks, conclusions about viability, value and utility about the implemented device came out. Most important points are:

- Modularity achieved with the cNGD enables robust foundations to build over new designs easily. This makes wider the possibilities for test-bed platform applications and facilitates CWSN research.

- Flexibility is an important concept affecting both communications and applications. Three RIs make the cNGD the only WSN test-bed platform capable to access three different frequency bands. Applications might implement a great range of functionalities making use of the expansion slots that cNGD encrusts.

- Scalability is a fact since the used MiWi^{TM} protocol provides support for variable network sizes up to 8000 nodes at its PRO version. Moreover, the employed protocol gives support for both P2P and mesh topologies.

- Firmware employed supposes an efficient way to deal with multiple interfaces. A common MiWi^{TM} protocol stack is shared among RIs and this supposes computational and memory savings. The firmware also provides a HAL to deal easily with the hardware features.
- The MCU is a Microchip PIC32 due to firmware requirements. The model chosen supposes the less featured MCU fulfilling minimal peripherals needed and offering a wider pin-out to avoid pin-multiplexing incompatibilities.
- Power switches driven by the MCU control the power supply at the RIs. These have been shown as a really valuable function at energy saving modes. Sleeping modes are successfully implemented and allow a great autonomy using the provided battery. On the other hand, RIs have shown a very low power consumption behavior, what also helps to extend the autonomy.
- Size achieved at the platform, together with anchorage options reveals a great usability and provide easiness facing application developments.

8.1. Further Studies

Facing the future of the platform, it is important to pay attention to some points. These points have been considered as highly convenient in order to increase performance and obtaining a better utilization of the system.

- To exploit the real possibilities that cNGD platform offers, a real test-bed deployment is required. Real cognitive strategies and performance must be evaluated in realistic scenarios. An implementation consisting in a standard sized WSN using cNGD nodes would be the next step to recreate a realistic CWSN. A test-bed deployment brings some necessities that are exposed throughout these future lines.
- It is important, specially when facing a test-bed deployment, to establish an OTAP (*Over The Air Programming*) system. This would facilitate the task of getting all the test-bed nodes programmed. In addition, cNGD is hardware-capable to host an OTAP system. Just proper software is required.
- Since keeping an 802.11 interface is desirable in a WSN, a custom shield could give this possibility to the cNGD. Expansion options on board the cNGD gives chances for Ethernet connections. Moreover, facing the test-bed deployment, an 801.11 gateway becomes essential for some kind of IP access, control and storage.
- CRmodule integration at the current firmware version is essential for a test-bed implementation. This module is responsible to manage all the cognition related data-flow and control. It supposes an indispensable portion to make create a real CWSN.
- Some firmware modifications claims to be done. A firmware adaptation to notify low-battery state might be an easy, valuable and useful implementation. On the other hand, a complete function to change RI bit-rates while operating would a powerful tool for CWSN investigation and would provide extra flexibility. On the other hand, functions to search for PANs and establish connection to them

is still needed. USB tracing modes still need for a further work, a circular buffer is needed. Furthermore, energy thresholds and zero-levels still need adjustments when sensing the radio spectrum.

- Once the line of RI designing was started, there is room to keep improving the design. Giving to the current design the chance to swap its antenna impedance matching circuitry, would enable the transceiver to operate over both 434 and 868 MHz. Currently there are not commercial tuneable transceivers for WSN. It even might include a wake-on radio system like the one proposed in [110].
- Try new chip MRF24XA[111], launched during the development of this project, might bring a better performance on communications over 2.4 GHz. A corresponding review must be taken, specially when facing the packet losses fact at unicast mode.
- Studying different possible antennas and respective performance at μTrans RI might provide perspectives to increase performance and therefore, improve communications.
- Many possible implementations are possible for the expansion options at the cNGD. Typical sensor modules on WSN applications could be embedded into a shield. Different gateways or communication options such as 3G, GSM (*Global System for Mobile*) or GPRS (*General Packet Radio Service*) could be of interest for certain applications. Even developing a generic empty board with soldering slots could be a cheap way to prototype shields.
- A review over the obtained performance and possibilities of less featured MCU, even changing the used architecture might set some guidances for future improvements on the platform, despite this supposes a firmware redesign.
- Optimization of the design. Current design is susceptible to suffer design optimizations. RJ-11 PGE programmer could be replaced by a simpler, smaller and cheaper option, or even be included at the header. Creating an unified clock signal for MCU and transceivers is possible and it would save energy on clock signals generation.
- A good complement for the OTAP system could be a wireless console system. This wireless console could provide wireless tracing of the platform or even debugging. This tool would be valuable facing application developments.
- It still exists possibilities for firmware improvements. An easier access to available peripherals at the headers might be carried out, or expand options through USB interface.