Enhanced wireless technology for body implants and sensors

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Body implants such as pacemakers and hearing aids have been used to counter organ dysfunction for decades. The WISERBAN project is making a giant leap in their development: aiming to provide smarter communications among such devices, with reduced size and lower energy consumption.

In the near future, people affected by health issues as varied as Alzheimer, diabetes, hearing loss, heart failure or even missing limbs could all have something in common: a smart, efficient, in-body or on-body device that makes their daily life easier and more enjoyable. To this end, the development of tiny and ultra-low-power wireless communications is key. It allows these devices to communicate changes in conditions and adjust treatments accordingly. Only limited autonomy and wireless connectivity can be achieved using today's wireless solutions because of their size and power consumption. Conscious of the fact that this limitation is currently holding back 'wireless body-area network' (WBAN) capability for use in lifestyle and bio-medical applications, the WISERBAN project brings together major medical-device manufacturers, research institutes and chip makers to overcome this obstacle.

WISERBAN is focusing on the extreme miniaturisation of 'body-area network' (BAN) devices. It touches on the areas ofradio-frequency (RF) communications, 'Microelectromechanical systems' (MEMS) and miniature components, miniature reconfigurable antennas, miniaturised and cost-effective system-in-package (SiP), ultra-lowpower MEMS-based radio system-on-chip (SoC), sensor signal processing and flexible communication protocols.

During an interview with research*eu results magazine, the project coordinator, Dr Vincent Peiris tells us more about the project's contribution to improving state-of-the-art technology, and how its outcomes will enhance comfort and access to ICT for impaired and disabled people of all ages. Dr Peiris is Section Head for RF and Analog IC Design at the Centre Suisse d'Electronique et de Microtechnique (CSEM) in Neuchâtel, Switzerland.

What are the main objectives of the project?

There is a growing resort to next-generation wireless body-area networks for smarter medical, healthcare and lifestyle devices. Networking sensors worn on the body or implanted in the body are being developed, and a key enabler of such technology resides in tiny and ultra-low power wireless communications. In this context, WISERBAN aims to develop an ultra-miniature wireless microsystem comprising a 2.4GHz radio, a microprocessor for the sensor data processing, and RF MEMS devices for improved radio performance, all combined in a 4 x 4 x 1mm3 system-in-package with power consumption of around a few milliwatts. The target is to achieve devices that are 50 times smaller, and with power demands that are 20 times lower than existing consumer products, which generally rely on classical solutions like Bluetooth.

What is new or innovative about the project and the way it is addressing these issues?

The WISERBAN consortium is unique as it is federated around four leading industrial partners - SORIN for cardiac implants, Siemens Audiology Solutions for hearing aids, Debiotech for insulin pumps, and MED-EL for cochlear implants - which together bring in stringent and market-oriented requirements. Their products are fairly different because some are implanted while others are worn on the body. Also, targeting health care comes with constraints that are not necessarily the same as for lifestyle demands. Nonetheless, it was possible to define commonalities with respect to the wireless communication layer, which allowed us to engineer a dedicated radio specification and architectural breakdown for driving the current technology developments.

The two major innovations brought by the WISERBAN device are its unique low-power radio architecture and its size: 4 x 4 x 1mm3. At the radio level, we created a unique combination of ultra-deep-submicron 'complementary metaloxide-semiconductor' (CMOS) circuits with a heterogeneous set of MEMS devices - such as 'bulk acoustic wave' (BAW) RF resonators, 'surface acoustic wave' (SAW) RF filters and lowfrequency 'silicon resonators' (SiRes)-whereas today's approach relies on CMOS-only chips which require several external and bulky passive components such as crystals and RF filters.

The joint usage of MEMS with CMOS enables much smaller SiP integration when compared to modules using CMOS chips, as well as the engineering of disruptive radio architectures which use the advantages of MEMS devices to compensate for limitations in the CMOS circuits - and vice versa. This allows for a highly efficient start-up time for the transceiver section, thereby enabling rapid wake-up of the radio. This is crucial for low power operation as it eliminates the unnecessary current consumption that normally arises from the slow start-up of classical radio architectures.

In parallel, we developed a miniaturised SiP approach for achieving the 4 x 4 x 1 mm3 target while being affordable from a commercial point of view. Current solutions, like three-dimensional (3D) silicon integration, suffer from technical complexity and are rather costly for silicon foundries to implement in their flows. With WISERBAN, the CMOS and MEMS devices are embedded within very tiny epoxy laminates, and these flat two-dimensional (2D) SiPs can then be stacked together by solder-bumping to realise tiny 3D SiPs. The cost-effectiveness and inherent modularity of this SiP platform allows it to be easily configured to address the variety of end-user requirements.

What are some of the difficulties you have encountered and how did you solve them?

WISERBAN is about pushing innovation into many wireless technologies, such as miniature antennas, radio chips, digital-processing circuits and MEMS devices, but also software for system control and for wireless sensor networking. System integration - which is about getting them to work together in a unique demonstrator or a product - is thus a very complex task and a major project challenge. It has required the development of rigorous top-down specification and architecture breakdown, making sure that each block takes into account its environing conditions and interfaces with other components. Research teams across several EU countries naturally tend to concentrate on the scientific challenges of their own blocks taken individually, so system integration has also been about ensuring efficient and regular interactions between them. Creating an enabling and stimulating environment for proper system integration and playing the role of system integrator has been a major task for CSEM as scientific coordinator of the project.

A concrete example is the successful realisation -at the first attempt-of the WISERBAN SoC, which is the system integration of several technology 'bricks' like MEMS and radio circuits with a 'digital signal processor' (DSP) on a single silicon die in 65nm CMOS. On the other hand, other technology bricks, such as the SiRes MEMS, have proved very challenging to achieve because an entirely novel fabrication, processing and encapsulation flow has to be invented, and this has proved to be lengthier than expected in order to deliver devices giving satisfactory performance. To solve such issues, synergistic interaction with another EU-funded FP7 project - GO4TIME2 which deals with similar MEMS issues - was established to deliver contingency technology items for the WISERBAN SiRes MEMS.

What are the concrete results from the research so far?

These include the first version of WISERBAN SoC, which integrates on a single chip in 65nm CMOS a complete MEMS-based transmitter and a digital signal processor of the icyflex family, and was functional at the first attempt. Currently the teams are working to integrate the remaining blocks for the final version of the SoC.

Another very interesting result is the availability of the first miniature antenna prototypes which have been developed taking into consideration the stringent environment and propagation conditions related to end-user housings (e.g. hearing-aid housing, cochlear implant housing). Both passive and active antennas - active meaning that the device incorporates tuning mechanisms to cover the entire 2.4GHz frequency band - have been developed and characterised successfully at laboratory level. The next step is to combine them with the WISERBAN SoC and verify proper functionality when implemented in the selected housings.

At MEMS level, several first prototypes were developed and demonstrated successfully, such as the BAW resonators and filters, and the SAW filters. First promising results for the SiRes MEMS have been shown on wafer-in-air, but need to be confirmed under vacuum packaging. The next step is to stabilise the SiRes packaging process, which is a critical challenge currently being addressed.

On the software side, the industrial end-user partners have elaborated a common framework for building the control software pieces. On the wireless networking side, a dedicated protocol stack was developed and optimised with respect to low-power communication for body-sensor networks. The potential of this protocol has already been demonstrated on a benchmark sensor network constructed with off-the-shelf radio circuits, in anticipation of implementing a WISERBAN network.

When do you expect the technology to start benefiting European citizens?

The technology should benefit EU citizens once the complete WISERBAN technology is installed in end-user products. This is expected around 2015 - maybe later for those products which are related to health care and hence require more certification steps. Specific technology bricks, like some circuits or MEMS devices, could be leveraged towards semiconductor products earlier, in 2014.

What are the next steps of the project, or next topics for your research?

Beyond the WISERBAN project, several topics have emerged forfuture research. WISERBAN is currently concerned with applications operated with tiny batteries - so a first research path would be to push system integration further by combining it with emerging energy-harvesting technologies that could collect energy from moving limbs, heartbeats, or body heat.

Another interesting path is the further reduction of the volume and size of wireless microsystems, by exploring disruptive radio architectures using next-generation CMOS technologies (e.g. down to 10nm CMOS) or beyond-CMOS technologies (based on nanomaterials). Such approaches pave theway towards zero-energy and virtually invisible communication devices, and will enable a plurality of novel health-care and bio-medical applications, such as smart skin for human prosthetics, unobtrusive monitoring devices for healthy living and ageing, networks of implants for assisting surgical interventions, or tiny implanted neuro-stimulation solutions for curing neurological disorders.

More information: cordis.europa.eu/projects/rcn/95472_en.html

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