Ambient functionality in MIMOSA from technology to services

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Abstract

The MIcrosystems platform for MObile Services and Applications (MIMOSA) is an European Integrated Project in the Information Society Technology (IST) priority. The goal of MIMOSA is to make Ambient Intelligence (AmI) a reality by developing a mobile-phone centric open technology platform. In MIMOSA vision, personal mobile devices act as the principal gateway to AmI. The technology platform consists of the present telecommunication technology platform augmented with the following new key building blocks: wireless sensors exploiting the RFID technology, highly integrated readers/writers for RFID tags and sensors, MEMS-based RF components and modules, low-power short-range radios, advanced integration technology and novel MEMS sensors for context sensitivity and intuitive user interfaces. In MIMOSA vision, the user feels and really is in control of AmI. AmI applications help people in their everyday life: the applications are useful, usable, reliable, and ethical issues have been taken into account in the design.

1. Introduction

MIMOSA project addresses Ambient Intelligent (AmI) applications where personal mobile device acts as a gateway to AmI, and ensures user being in control in the applications. In the MIMOSA vision, the user progressively gets in control of his AmI environment, instead of being a passive object as in classical AmI approaches. He will be able to interact with everyday objects and the environment as well as monitor and control environmental and health parameters.
Microsystems technology is the key enabling technology for realizing the MIMOSA platform due to its low-cost, low power consumption, and small size. The generic Microsystems building blocks for AmI are identified and developed. These blocks provide the required functionality for the local connectivity, context sensing, intuitive user interface, energy autonomy, and Microsystems integration technology.

MIMOSA aims at developing an open platform to fulfill the requirements of AmI. This platform will be composed of different components with close interactions:

- WP1: Applications and services
- WP2: System architecture
- WP3A: Short range communication
- WP3B: Context awareness and actuation
- WP3C: User interfaces to AmI
- WP3D: Energy scavenging
- WP4: Microsystems integration

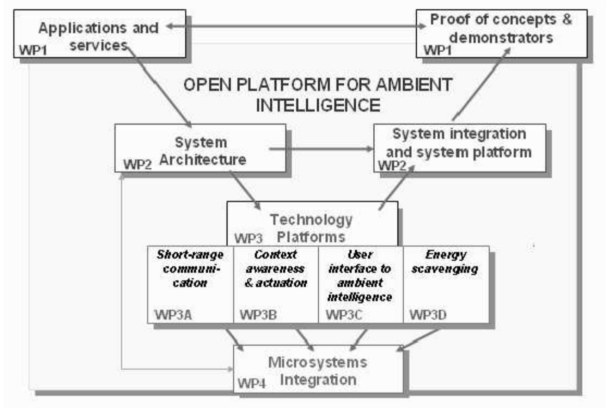

Figure 1*: Structure of MIMOSA project*

2. Applications & services

Aim of the work package WP1 is to ensure that the development of MIMOSA core technology is based on the user needs and that the resulting technical solutions will be easy to use, useful and acceptable from the user point of view as well as applicable in different fields.

WP1 take care that the MIMOSA project defines and maintains a common vision of the future, in form of usage scenarios. These scenarios are used as the basis for user and application requirements for MIMOSA technology and architecture. MIMOSA is focused on four representative consumer applications fields where user mobility can be combined with measurements of the user and her environment: sports, fitness, health care and housing (Figure 2).

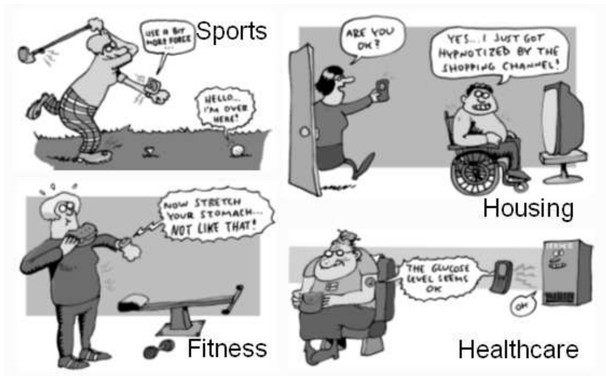

Figure 2: *Example of MIMOSA scenarios*

Scenarios (36 short stories) were defined at the beginning of the project and are described in a public deliverable available on the public website [1]. The scenarios describe several alternatives to utilize MIMOSA technology. The scenarios mix technical solutions that are available already today, solutions that will become possible with MIMOSA technology and also some “hype” elements – applications for which we do not currently know the technical solutions.

The MIMOSA applications share many common features related to collecting measurement data, communicating with objects in the environment, identifying contexts, activating applications and so on. These features include common usage patterns that can be illustrated as use cases [2].

3. System architecture

Aim of the work package WP2 is to create the overall MIMOSA architectural specification (OMAS) based on the analysis of requirements of applications identified in WP1. The overall architecture for the enabling technology for AmI should allow new applications and services. Furthermore, WP2 creates more specific architectural descriptions of local connectivity, intelligent sensors, context information processing and novel user interfaces for AmI.

Target for the MIMOSA architecture is to provide fast, flexible and comprehensive platform for combine new connectivity, sensor & user interface hardware and novel applications to new ensemble. Architecture is not targeted to products as it is, but rather to give fast test and development possibilities when architecture platform is ready while applications and hardware are under development. Architectural platform is also intended to be as reusable as possible.

The architecture of the MIMOSA platform can be divided into three physical entities (Figure 3):

- Mobile terminal
- Sensor Radio Node
- Active RFID node or Passive RID tag

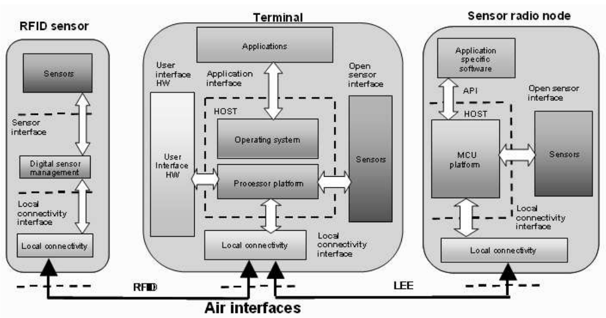

Figure 3*: Overall architecture specification (OMAS)*

Terminal device is the trusted device of the user. Most important blocks of the terminal are processor platform, user interface, embedded sensors and local connectivity module. The local connectivity module offers connection to all surrounding MIMOSA sensor devices from terminal.

Sensor radio node consists of micro-controller based host, local connectivity module and sensor. Micro-controller has processor core that will enable application specific software running on the sensor node this includes communication protocol stack and sensor information processing. Radio sensor node has own radio, so it can advertise services that are available and communication range is longer that RFID based system.

RFID sensor is very integrated sensor system. Active and passive tags will have common OMAS architecture. The usage of optional external power supply will determine whether a TAG is active or passive. Local connectivity is the most important part of this system.

The local connectivity means physical ability with the associated control process to interact with the surrounding devices. Two interfaces are implemented:

- For the RFID air interface, the protocol of the ISO 18000-4 norm is chosen. A simplified version was implemented for which the tag has four major states: Power-off, Ready, ID (tag is trying to identify itself to the interrogator) & Data-exchange (tag is know to the interrogator and was selected)
- For air interface, Low-End Extension (LEE) [3] is chosen as the technical solution for MIMOSA sensor radio. LEE operates at the 2.45GHz ISM band. The strength of LEE solution is in the optimization for sensor type of devices and ability to re-use Bluetooth RF parts.

4. Short-range connectivity

Objective of the work package WP3A is to create and design the key components for a short-range wireless communication (Figure 4):

- Wireless Remote Power Sensor (WRPS)
- Reader/writer for WPRS
- Ultra low-power wake-up radio
- Battery Powered sensor (BPS) node radio

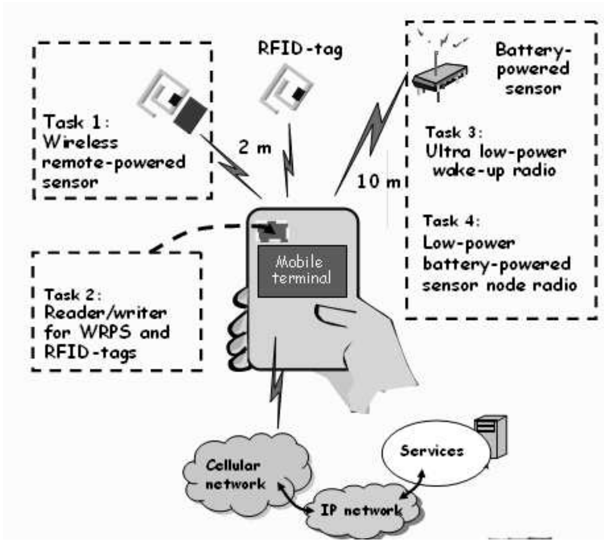

Figure 4*: Short range connectivity components*

The first component is a WRPS with a low-power readout circuit for a capacitive sensor and communication based on backscattering technique at the 2.45 GHz ISM bands. These wireless sensors can be described as RFID tags augmented with a sensing functionality. The sensors make use of the RFID technology by sharing the same circuit blocks and the same communication protocol.. These wireless sensors consist of an antenna, an IC consisting of a voltage rectification circuit, microcontroller, memory, and the sensor interface circuit. Alternatively, the sensor can be a separate component. The reader/writer unit provides operational power for the wireless sensor.

The second component is a radio module for the mobile handset that could be used both as a reader/writer (i.e., interrogator) for WRPS and RFID tags in the 2.45 GHz ISM band. The interrogator is integrated with a Bluetooth radio of the mobile handset during. Therefore, a particular attention is paid to a maximum compatibility between the Bluetooth radio and interrogator functions. The reader/writer consists of three circuit board: the RF circuit board including a quasi-circulator who exhibits a high isolation level between Rx & Tx, the A/D and D/A converter circuit board and a commercial DSP board platform for embedding the communication software.

The third component is an ultra low-power wake-up radio. This radio will be turned on all the time and will then wake-up the main radio whenever any message has to be demodulated. Simulations show that significant increase in battery lifetimes can be obtained by using a wake-up radio. This wake-up radio will use all the high-Q passive components available to reduce the radio's power consumption. For example, the radio uses a RF front-end filter built with BAW resonators taking advantage of their high Q-factors [4]

The last component is a battery powered sensor node radio based on low-power MEMS-based VCO at 2.4 GHz and also other MEMS-based RF circuit blocks. Objective is to design VCO whose frequency is tuneable to fit with the ISM frequency band (2.4 to 2.48GHz) and the temperature & process variation. The LC tank of the VCO is based on high Q inductor fabricated on glass and an integrated tuneable capacitor. The VCO architecture uses a reference oscillator based on MEMS resonator allowing very good phase noise performance.

5. Context awareness & actuation

The work package WP3B focuses on the development of Microsystems technologies and components for a wireless context-sensing network. Two major classes for context awareness can be differentiated:

- The personal user context (activity, fitness, physiology, health…): the sensors considered are located on or close to the user body, in the mobile terminal
- The environmental context (location, comfort, nearby people, local services…): the sensors are located in the surroundings. The environmental context will be monitored by RFID sensors.

The first objective of this work package is the development of sensor for the continuous monitoring of lactate, based on new polymer micro-needle array to extract body fluid (Figure 5).

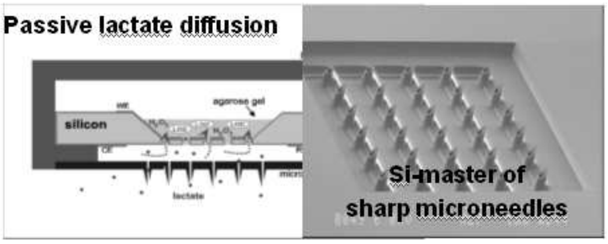

Figure 5*: Sensor for the continuous monitoring of lactate*

This micro-needle array is based on polymer replication from micro-machined silicon masters. A novel lactate sensor is developed for continuous fitness monitoring in a smart plaster system. The amperometric silicon sensor chip contains the enzyme lactate oxidase. The lactate molecular diffusion to the enzyme can be controlled by a perforated membrane. The design and technology of the lactate sensor is adapted to allow a fluidic coupling to the micro-needle array.

The second objective is the development of low power 3–axes gyroscope for motion monitoring (Figure 6). The gyroscope has the following novel characteristics:

- Able to sense rotary motion around multiple axes
- Surface micromachined process will allow integration of three axes on the same die (< 10 mm^2).
- Active structures will require electrostatic excitation and provide capacitive readout
- Vacuum encapsulation will be used to reduce damping and then energy loss (< 1mW) for driving
- Capable of sufficiently high resolution (i.e. 0.05 degree/s) with 10Hz bandwidth and overall stability

In order to reach such performances, thick sensitive element (15 to 40µm) & new driving concept, based on non-linear high-Q excitation resonance oscillation are developed.

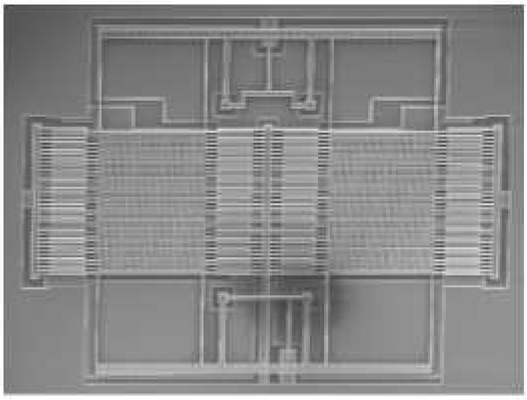

Figure 6*: Micro-machined 3-axis gyroscope*

6. User interface to ambient intelligence

In the work package WP3C, the focus is set on user feedback to the context provided by third device such as display or audio background. Three major interaction domains are investigated: acoustical, motional and optical feedback.

The transducer system can be a part of the personal trusted device or a separate portable unit connected to it. Various user interface concepts are analyzed and evaluated based on applications scenarios taking operational and commercial aspects into account.

The optical interface is one of these user interface developed in the MIMOSA project (Figure 7). The goal is the development of a miniature projection display with VGA resolution that is small enough to be incorporated into a mobile phone. The concept of the micro projector is based on the development of a two-axes MEMS scanner that has to deflect a collimated laser beam fast enough in x and y in a raster pattern so that a VGA-resolution standard with 480lines, 640 pixels per line and 30 frames per second can be achieved. The MEMS scanner prototypes are fabricated based on Microsystems technology.

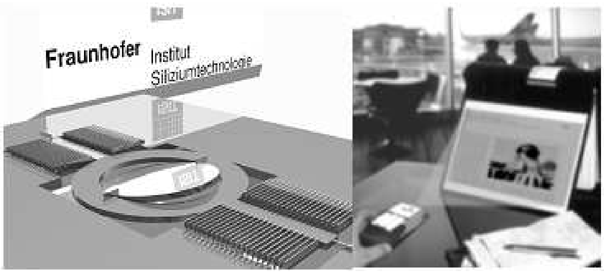

Figure 7*: Micro-mirror for laser scaning micro-projector*

7. Energy scavenging

The work package WP3D is mainly focused on the developments of energy harvesting components aiming at powering the sensor nodes located in the environment. Based on the fact that these sensor nodes will be activated by the mobile terminal RFID reader for downloading data, the energy to be gathered is only required for powering the sensor between two data acquisitions.

Among the different energy scavenging sources (RF, photovoltaic, thermoelectric….), special investigation has been done on electromagnetic energy scavenging. A preliminary study showed that RF scavenging systems are not efficient if they are not designed and suited to precise applications and their specific frequency bands. Then, the work was focused on system dedicated to mobile phone environment (GSM900MHz frequency bands). The RF scavenging system is powered by radiations emitted by the mobile phones to the base stations. An antenna (Figure 8) was simulated, designed, fabricated and characterized in anechoid chamber. The measurement showed that for this omni-directional antenna, the maximum gain is about 1.4dBi allows a 1.9mW (respectively 500µW) of scavenged power at 2 meters (respectively 1 meter) of a mobile phone with an emitted power of 2W. The feasibility was then demonstrated and the antenna has now to be associated to an electronics and rectifier stage to form a complete energy scavenging module able to power a small system.

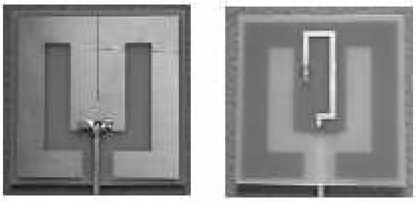

Figure 8*: Antenna for energy scavenging in GSM band*

8. Microsystems integration

WP4 focuses in Microsystems integration. It addresses on the one hand integration issues to serve the demands of other work packages, according to MIMOSA global scheme, and provides the demonstrators for WP1, and on the other hand new developments. The latter are specifically the development of MEMS components starting from the existing IC platform technology, new material integration study to enlarge the platform capability, -namely horizontal co-integration-, or new integration methods serving vertical co-integration (Figure 9). Both System-in-Package (SiP) and System-on-Chip (SoC) strategies are used alternatively for integration of Microsystems and RF-MEMS components.

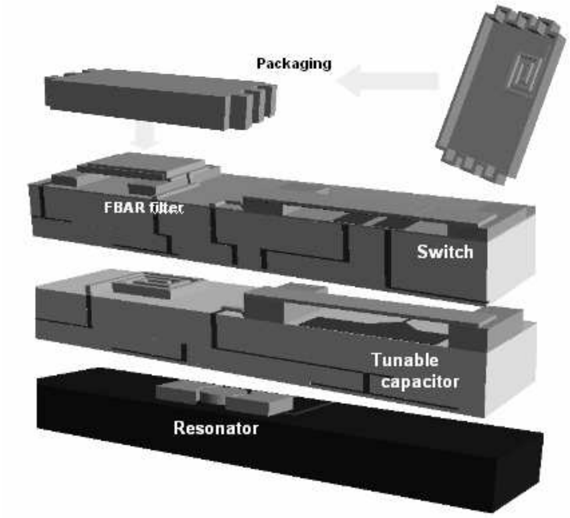

Figure 9: *Vertical integration of Microsystems*

9. Conclusions

The MIMOSA project covers a very broad range of topics, from end-use scenarios to enabling technologies and device manufacture. One key results of the project is the establishment of a strong link between technologies and applications. In the MIMOSA vision, a clear picture is emerging of how the mobile phone centric sensor applications and MEMS technology developments are working together. A technology-scenario dialogue has successfully started and will be strengthen in the future between the application and services and the other technology work packages.

The scenarios defined initially will be continuously evaluated with end-users, applications developers and technical experts. These feedback will be use to refine the scenarios so that it represent the common vision of the project of how MIMOSA technology will look and feel in everyday life.

Acknowledgements

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