e-SENSE
IST-4-IP-027227

Capturing Ambient Intelligence for Mobile Communications through Wireless Sensor Networks

Mirko Presser, University of Surrey
28/02/08
Brussels

Project Facts

Project Duration 24 months, Kick Off: January 2006
EU Project IST-4-IP, 027227

Project Finance
EU contribution
6,300,000 Euros
Total estimated cost
10,000,000 Euros
Total Effort over 24 months
950 Person Months

Project Lead
CEA-LETI Laurent Herault
Technical Management
UniS Mirko Presser
Administrative Manager
ALMA Giuseppe Candela
Vision and Key Ideas of e-SENSE

- Efficient Wireless Sensor Networks
- Heterogeneity of Sensor Network
  - Body Sensor Networks (BSN)
  - Object Sensor Networks (OSN)
  - Environment Sensor Networks (ESN)
- Integration of Sensor Networks into B3G systems and platforms
- With the goal to capture context for Ambient Intelligence (AmI) and AmI Systems
Key Achievements – 1

• The e-SENSE assumptions and requirements
  – based on 26 diverse application scenarios, decomposed through novel tools into context building blocks and their requirements and
  – exposed to acceptance studies.

Key Achievements – 2

• End-to-end e-SENSE system architecture
  – Spanning from the individual nodes to the service platform, specifying
    • the “e-STACK” protocol stack architecture,
    • the gateway extensions
    • WSN integration into IP Multimedia Subsystem (IMS) service platform
  – The scope of the e-SENSE system architecture goes well beyond the ZigBee standard.
e-SENSE Protocol Stack Architecture

- Application Subsystem
  - Application 1
  - Application 2
  - Application N

- Middleware Subsystem
  - MW Data Transfer Entities
  - MW Control Entities

- Connectivity Subsystem
  - CO Data Transfer Entities
  - CO Control Entities
  - PHY Entities

- Management Subsystem
  - Program Service
  - Service Discovery
  - Node Discovery
  - Time Synchronization
  - Security Manager
  - Node Manager
  - System Manager

- WSN Applications

- Connectivity Subsystem
  - data transfer service
    - energy-efficient data transfer
    - QoS-based routing, segmentation, encryption, retransmission
    - tree, mesh, or cooperative routing
    - data-centric filtering at receiver
  - configuration/support service
    - form star, tree, or mesh network
    - join/remove device to/from network
    - synchronize node
    - retrieve location position

- Middleware Subsystem
  - node-centric data service
    - reliable unicast/multicast transport
    - priority-based congestion control
  - data-centric access service
    - publish/subscribe messaging
    - semantic mapping of high-level data
    - distributed data processing
    - filtering/aggregation of data

- Management Subsystem
  - programming services
  - support services
  - management services

- e-SENSE System Architecture

- Management Subsystem
  - Service Promoter
  - Gateway Manager

- Middleware Subsystem
  - MW Interaction Manager

- Connectivity Subsystem
  - Gateway extensions

- Protocol stack architecture for WSN systems

WSN Applications

- e-SENSE

Information Society
Technologies
Integration into IMS

- Developed dedicated context information service for IP multimedia subsystem (IMS) of B3G system
  - reusable service for all e-SENSE context-aware applications and services
  - access sensor-based context information with standardized interfaces/protocols (IMS, SIP)
  - implementation with service enabler and gateway extensions

Key Achievements – 3

- Protocols, algorithms and mechanisms for the CO, MI and MA subsystems include and Protocol Stack solutions (3 instantiations):
  - Energy efficient air-interfaces for WSN achieving 20nJ/bit;
  - Innovative WSN communication mechanisms tailored to the e-SENSE application scenarios in terms of protocol elements for MAC, networking, transport and management;
  - Cross-optimisation of protocol elements and design of three WSN protocol stack instantiations for specific application scenarios;
  - Distributed services, which address common services such as localisation/positioning, timing and synchronisation and service discovery;
  - Distributed data processing, which address mechanisms to enable collaborative processing and context awareness support;
  - Data centric resource management, which aims to optimise computing and communication resources in a data-centric network;
  - An integrated WSN middleware solution, including service discovery, resource management and semantic transport middleware, based on a publish/subscribe model.
Example protocol stack instantiation (b)

WSN systems deployed in environmental or object sensor network applications requiring localisation and positioning.

The protocol stack supports multi-hop communications and limited mobility support of sensor nodes within the WSN system and is further optimised for in-network processing.

Ultra low power PHY : Letibee

- **Description**
  - An IEEE802.15.4 compliant PHY implementation targeting 20nJ/bit

- **Usage**
  - BSN, ESN

- **Highlights**
  - Functional chip
  - World record / power consumption

- **Limits**
  - Trades sensitivity for power consumption

**Highlight**

<table>
<thead>
<tr>
<th></th>
<th>Simulated (mA)</th>
<th>Measured (mA)</th>
<th>Extrapolated (mA)</th>
<th>Extrapolated (nJ/bit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RX</td>
<td>3.45</td>
<td>6.65</td>
<td>3.8</td>
<td>18</td>
</tr>
<tr>
<td>TX</td>
<td>5.6</td>
<td>9.18</td>
<td>6.33</td>
<td>30</td>
</tr>
</tbody>
</table>
**Integrated PHY-MAC-NWK: RoCoDiLe**

- **Description**
  - An integrated location based convergecasting MAC-NWK protocol with PHY cooperation

- **Usage**
  - High density ESN, typically for the industrial application space

- **Highlights**
  - Integrates distributed and cooperative routing with leapfrogging
  - Novel metrics for relay selection

- **Limits**
  - Precise location knowledge required
  - No mitigation of dead end problem in random topology

---

**Localisation algorithms**

- **Novelty:**
  - Location Awareness Engine (LAE)
  - Mass-spring localisation

- **Highlights of Location Awareness Engine**
  - Integration framework
  - Flexibility in applying various localisation algorithms with different inputs
  - Mobility support
  - Hard/software implementation

- **Highlights of Mass-spring localisation**
  - Reduced communication overhead
  - Reduced computation overhead
  - Multi-hop localisation
Service discovery

- **Novelty:**
  - Dynamic service clustering
  - Fully distributed

- **Highlights:**
  - Minimized computational cost
  - Minimized communication cost
  - Stability

![Activation and Maintenance Graphs](image)

**Key Achievements – 4**

- **Concept validations and show cases**
  - Low-power RF PHY – Hardware demonstrator for ZigBee communications at 20nJ/bit
  - Energy efficient communication and operation – e-STACK;
  - Distributed data processing, and services – Smart Signs;
  - Context capture and availability – Mood application;
  - Integration with B3G systems and services in an end-to-end system, reaching from the physical phenomena sensed by the sensors up to the service platform.
**Architecture Realisation**

- **e-SENSE protocol stack**
  - configured to requirements of three application scenarios
    - **body sensor network** (BSN)
    - **environment sensor network** (ESN) with and without localization support
  - protocol elements designed and developed in WP3/WP4

- **E2E implementation of BSN application scenario in WP5**

**Impact/Conclusions**

- **e-SENSE closed the gap with WSN research conducted outside Europe**
  - e-SENSE architecture goes well beyond ZigBee
  - 20nJ/bit 802.15.4 compliant transceiver

- **e-SENSE achieved “world first”**
  - Service Platform Integration of WSNs

- **e-SENSE contributed in its two year lifetime to major standardisation bodies:**
  - ZigBee Alliance (Telefonica)
  - IEEE802.15.4 (CEA-Leti)

- **e-SENSE produced high quality specifications (D.2.2.1 and D.2.2.2) that can in its current form flow into Standardisation (e.g. ETSI ISG)**
The e-SENSE Success

- Spin-Off: SENSINODE and SMEs benefited from e-SENSE
- Over 70 quality publications and over 35 quality public deliverables
- Contributions to Standards – ZigBee and IEEE802.15.4
- Real tangible outcomes/prototypes
  - Audio-Visual Demonstrations
  - Service Platform integration
  - Body Sensor Network and “Mood”
  - Environmental Sensor Network and “Smart Signs”
  - ULP transceiver achieving 20nJ/bit
  - Many functioning prototypes for protocol development
- e-SENSE consortium and work is partially continued in SENSEI

All in 2 Years with 24 partners and 6.3MEuros

Thank you

Coordinator Details:

<table>
<thead>
<tr>
<th>Partner</th>
<th>DCIS Department, CEA - LETI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinator Name</td>
<td>Laurent HERAULT, PhD</td>
</tr>
<tr>
<td></td>
<td>Head of Telecommunications Program</td>
</tr>
<tr>
<td>Email</td>
<td><a href="mailto:laurent.herault@cea.fr">laurent.herault@cea.fr</a></td>
</tr>
<tr>
<td>Address</td>
<td>Centre de Grenoble</td>
</tr>
<tr>
<td></td>
<td>17 rue des Martyrs</td>
</tr>
<tr>
<td></td>
<td>38054 Grenoble Cedex 9</td>
</tr>
<tr>
<td></td>
<td>France</td>
</tr>
<tr>
<td>Telephone</td>
<td>+33 (0)4 38 78 95 15</td>
</tr>
<tr>
<td>Fax</td>
<td>+33 (0)4 38 78 51 82</td>
</tr>
</tbody>
</table>

Technical Manager Details:

<table>
<thead>
<tr>
<th>Partner</th>
<th>CCSR, The University of Surrey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Manager Name</td>
<td>Mirko PRESSER</td>
</tr>
<tr>
<td>Email</td>
<td><a href="mailto:m.presser@surrey.ac.uk">m.presser@surrey.ac.uk</a></td>
</tr>
<tr>
<td>Address</td>
<td>Stag Hill</td>
</tr>
<tr>
<td></td>
<td>Guildford, Surrey</td>
</tr>
<tr>
<td></td>
<td>GU27XH</td>
</tr>
<tr>
<td></td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Telephone</td>
<td>+44 (0)1483 68 9800</td>
</tr>
<tr>
<td>Fax</td>
<td>+44 (0)1483 68 6011</td>
</tr>
</tbody>
</table>