D1.1b: State of the art review

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Abstract.
IST EU STREP project FP7-258888 – GREENERBUILDINGS
Deliverable D1.1b – This document presents the revised state of the art review of GREENERBUILDINGS regarding initiatives, techniques, and standards with a related focus to GREENERBUILDINGS. The document describes the methodological approach, review summaries, and conclusions with regard to the objectives of GREENERBUILDINGS.

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Refinements in response to reviewer comments

Based on the reviewer comments, the following additions and refinements of this deliverable have been made:

1. **Additional review of initiatives.** Several additional projects and standards have been included in the review. These reviews include the projects HOMES (Sec. 4.37), the follow-up project SCUBA (Sec. 4.38), and Alwen (Sec. 4.39).

2. **Additional review of standards.** In addition, several additional standards were included in the review: EIB and KNX-RF (Sec. 5.31), OASIS (Sec. 5.48), oBIX (Sec. 5.49), as well as the standards related to smart meters: ANSI C12.18 (Sec. 5.42), C12.19 (Sec. 5.43), C12.21 (Sec. 5.44), IEC 61107 (Sec. 5.45), IEC 62056 (Sec. 5.46), and the Google Power Meter project (Sec. 5.47). The review of IEEE 802.11 (Sec. 5.30) was refined to include proprietary standards. Finally, the concepts OPC-UA and DPWS were included (Sec. 5.50 and 5.51).

3. **Revision of review structure.** Following the reviewer suggestions, standards and techniques reviews have been separated. Examples of relevant techniques are now reviewed at the end of Chapter 5.

4. **Revision of review summary and conclusions.** Review summary sections in Chapter 3 have been revised to provide a more focused description of the specific GreenerBuildings contributions as a result of the review. Moreover, the summary section has been refined to describe the key features of GreenerBuildings that represent important novel contributions to previous and on-going research efforts. The utilisation of standards by the GreenerBuildings framework has been clarified, e.g. regarding the foreseen communication of sensors and actuators. To this end, retrofitting requirements prescribe that the GreenerBuildings framework needs to remain flexibly customizable.

Changes

Version	Date	Author	Changes
1.0	28.02.2011	TUE	Final version submitted to the European Commission, to be considered for the project review.
1.1	13.02.2012	TUE	Revised revised version submitted to the European Commission, corresponding to the refinements requested by reviewers.

Contents

Chapter 1

Introduction

Efficient energy use in buildings is essential to reach the energy consumption targets as, e.g., established through the European Climate Change Programme (ECCP) [ECC]. In particular, large public and semi-public buildings are key targets to improve energy use through novel ICT-based solutions. An important reason is that public buildings are challenging to maintain manually in an energy-efficient mode, due to size, different stake holders involved, and dynamic usage patterns. Many public and semi-public buildings are erected in a monolithic fashion, using fixed technical installations and services. This static operation weakly reflects actual usage.

Since the 2000's several steps have been made to optimize energy efficiency in buildings through novel materials, design, and construction, e.g. in the European GreenBuilding Programme (GBP) [Gre]. While material and construction concepts as investigated in GBP remain important, technology advances in embedded and ubiquitous systems start to refining this picture. During the last five years, several projects and approaches had been initiated to investigate novel ICT-controlled building solutions worldwide. While first achievements have been recently obtained from these efforts, key elements related to the actual use of public and semi-public buildings through their occupants and visitors were not sufficiently addressed. While conceptual benefits of occupant-related building control approaches have shown energy saving benefits, e.g. in [AFWH05, LFA02, Dav99], their feasibility must be confirmed in real-life installations. In parallel to optimizing energy consumption and performing automated adaptations, user comfort continues to be an essential success criteria for ICT-based solutions.

This document reviews state-of-the-art in ICT-based initiatives, techniques, and standards related to the GREENERBUILDINGS goals on building-distributed sensing, occupant behavior recognition and context interpretation, middleware-controlled systems, and several further aspects. The primary goal of this consortium-wide effort was to identify potential interaction and (re-) use opportunities, as well as to further elaborate the GREENERBUILDINGS concept. The technical requirements for GREENERBUILDINGS are subsequently detailed in Deliverable D1.2.

To leverage from activity and contextual knowledge towards energy-efficient building operations, the GREENERBUILDINGS framework must be retrofitted into existing building structures. Consequently, existing BMS and communication infrastructure need to be used. Obviously, if the infrastructure does not yet exist, it needs to be set up. This review aims thus to identify potentially relevant technologies and standards, but is not intended to select a single standard only.

Several scientific challenges related to the acquisition and use of occupant behavior information for building adaptations persist. Once this information is available, appropriate strategies must be derived to coordinate large building installations and incorporate user control into the automatic building adaptation processes.

The review presented in this document started from selected key initiatives, techniques, and standards, that are related to GREENERBUILDINGS. Analysis of the works were performed and subsequently conclusion points were derived regarding the focus of the GREENERBUILDINGS approach.

The outline of this document was consequently chosen to reflect this approach. Chapter 2 introduces the analysis strategy and applied selection criteria in the review. Chapter 3 subsequently summarizes the analysis made and presents conclusions regarding the GREENERBUILDINGS approach. Chapters 4 and 5 comprise of the analysis summaries made for individual efforts.

Chapter 2

Review methodology

Achieving energy efficient operation of buildings is a topic of ongoing research. It has been reinforced recently due to the recognised need to elevate overall energy efficiency. GREENERBUILDINGS joins these efforts on evaluating solutions for energy-efficient building operations. However GREENERBUILDINGS aims at investigating the potential of pervasive computing in buildings. In particular, GREENERBUILDINGS aims at leveraging from occupant activity and building context information to enable benefits in energy efficiency for large public and semi-public buildings.

This chapter describes the methodology that was assumed in reviewing previous and on-going works and in concluding on their relevance for GREENERBUILDINGS.

2.1 Evaluation of previous and on-going related works

The GREENERBUILDINGS project aims at a multi-disciplinary approach, which incorporates various fields of on-going ICT research and relates to efforts that make buildings more energy efficient. To identify and select relevant related works, key technologies and applications were derived that are relevant to the GREENERBUILDINGS approach. These technologies and applications are detailed below:

- **Domotics & building operational services.** GREENERBUILDINGS builds on control functions available in building installations. Such installations have been frequently considered in the fields of domotics and building automation. Thus, existing domotics and building operational service solutions could provide relevant base technologies to adapt a building's operation regarding its current use.
- **Sensors & wireless technologies.** Classically, buildings have been sparsely monitored using sensor and wireless technologies. To realise the physical layer in the GREENERBUILDINGS system architecture however, monitoring and communication are essential functional elements. Sensing was investigated with a focus on

occupant activity and building context. Wireless solutions were reviewed to address retrofitting of the GREENERBUILDINGS architecture in existing buildings.

- **Context & activity recognition.** The energy-based adaptation of buildings in GREENERBUILDINGS essentially builds on information obtained from occupant activities and further building context types. A main challenge for the feasibility of activity recognition in GREENERBUILDINGS is its adaptation to large, public buildings. Consequently, review efforts have targeted works that could contribute to providing consistent information for automated building control.

- **Middleware & compositional approaches.** Pervasive middleware solutions could unite the functional components of the GREENERBUILDINGS monitoring and control architecture. Thus, approaches to implement the compositional layer in GREENERBUILDINGS are relevant for control, composition, and orchestration of services.

- **System architecture.** GREENERBUILDINGS aims at addressing large-scale buildings, where installations with 1000 and more networked nodes. System architecture choices must support the scalability and robustness of such installation sizes across all system layers.

- **Smart grid.** The GREENERBUILDINGS framework naturally relates to the smart grid. Information to control a building's energy consumption may originate from the grid. Similarly, the information regarding actual use patterns, which are available in the GREENERBUILDINGS framework may be relevant to optimise energy management and balancing in the smart grid.

Besides the key technologies and applications described above, several technical requirements can be identified [1] that qualify individual works in its relation to GREENERBUILDINGS. The following key performance criteria have been considered in this review to incorporate such requirements:

- **Energy efficiency.** Has the energy efficient operation of the ICT-based solution been addressed?

- **Scalability.** Have issues regarding different system complexities and the consequential needs for scalable solutions been addressed in the architecture?

- **Privacy.** Does the work address privacy of obtained information?

- **Costs.** Have cost been considered in the solution? What are the costs for realising the approach?

- **User comfort.** Was comfort of users addressed and measured?

[1] System requirements are further detailed in Deliverable D1.2.

- **Availability.** Was the solution's performance regarding permanent availability and real-time operation assessed?
- **System reliability.** Was reliability of the solution evaluated or specifically addressed?
- **Data security.** Have specific means been implemented to maintain security against attacks or other data security infringements?
- **Dynamicity.** Have dynamicity constrains or goals been addressed in the solution's architecture?
- **Standard compliance.** Have standardised concepts or solutions been incorporated in the work?

In combination, technologies and applications, and performance criteria form a decision matrix as shown in Table 2.1. Based on initial proposals and short abstracts of previous and on-going works, a scoring of the work's relevance was made using Tab. 2.1. Subsequently, relevant works have been selected for further review based on the scores. While this procedure does not yield an exhaustive coverage of related works, it ensured that key examples of approaches and efforts were captured. The criteria matrix was particular useful to maintain balance and coverage of technologies and performance criteria during the selection process.

2.2 Review implementation

The review of previous and on-going works was split into three categories, which have a distinct focus:

1. **Initiatives.** The initiatives reviews focused on research-oriented projects that aim at on one or more key technologies and applications relevant to GREENERBUILDINGS (as detailed above).
2. **Relevant techniques.** The techniques reviews focused on technologies and approaches of high relevance to realise the goals of GREENERBUILDINGS. For example, techniques include building energy management systems with sensors to estimate energy consumption.
3. **Existing standards.** The standards reviews focused on established procedures and technical solutions with relation to the foreseen GREENERBUILDINGS approach. For example, standards have been established for in-building communication infrastructures that can be used for the networking foreseen in GREENERBUILDINGS.

Each review was performed according to a fixed outline. For initiatives this structure was divided into the following sections:

- **Abstract.** A short description of the initiative.
- **Goals.** An overview of the available or expected goals of the initiative.
- **Approach.** A description of the approach that was used to achieve the goals.
- **Outcome.** A summary of important results of the project. The results were assessed from realised installations, e.g. of a developed framework, and from publications made.
- **Relation to GREENERBUILDINGS.** A description of essential aspects that relate the initiative to GREENERBUILDINGS, with focus on key technologies and applications (as introduced above), where relevant:
  - Domotics & building operational services
  - Sensors & wireless technology
  - Context & activity recognition
  - Middleware & compositional approaches
  - System architecture
  - Smart grid

  The relations of an initiative to the GREENERBUILDINGS approach are furthermore summarised in a criteria matrix, as shown in Tab. 2.1. Entries represent areas in which the initiative has made or is planning to make contributions. Techniques and standards utilised by the particular initiative serve as table entries.

	Domotics & building operational services	Sensors & wireless technology	Context & activity recognition	Middleware & compositional approaches	System architecture	Smart grid
Energy efficiency						
Scalability						
Privacy						
Costs						
User comfort						
Adaptability						
System reliability						
Data security						
Dynamicity						
Standard Compliance						

Table 2.1: Criteria matrix used to select and evaluate individual initiatives. Entries represent areas in which the initiative has made or is planning to make contributions.

For reviews of techniques and standards, a similar reporting structure was utilised. Simplifications were made to account for the generic and fundamental nature of techniques and standards. The following structure was used:

- **Abstract.** A short description of the technique or standard.
- **Relation to GREENERBUILDINGS.** A description of essential aspects that relate the initiative to GREENERBUILDINGS, with focus on selected performance criteria (as introduced above), where relevant:
  - Energy efficiency
  - Scalability
  - User comfort
  - Dynamicity & adaptability
  - Security & privacy
  - Costs

Finally, summaries were derived from the review analyses of initiatives, techniques, and standards with regard to the GREENERBUILDINGS scientific objectives as they are stated in the Description of Work. In particular, efforts were made to describe which initiatives could contribute to achieve the GREENERBUILDINGS scientific objectives. For this purpose, the following two questions were answered for each scientific objective:

- Which initiatives provide useful results that could be reused in GREENERBUILDINGS?
- What contributions will be made by GREENERBUILDINGS beyond the state-of-the-art?

Document structure

The remainder of this document is structured as follows: Chapter 3 summarises the review analyses made among initiatives, techniques, and standards with regard to the GREENERBUILDINGS scientific objectives. The following chapters detail the reviews for initiatives (Chapter 4), and techniques and standards (Chapter 5) respectively.

Chapter 3

Analysis summary

This chapter presents conclusions that were drawn from the reviewed initiatives, techniques, and standards. It summarizes results applicable to GREENERBUILDINGS (i.e. what reuse opportunities GREENERBUILDINGS may have), and what contributions GREENERBUILDINGS will add above to the current state-of-the-art with regard to each GREENERBUILDINGS objective.

3.1 Objective 1, Efficient self-powered activity & context sensing

As stated in the DOW, Objective 1 targets efficient ultra low power and energy harvesting sensing of user activity, building utilization and building context. The main requirements and outcomes of the objective are classified as: Sensors have to be able to be integrated in existing buildings, sensors require minimal installation and maintenance efforts, strategic and optimal physical location of sensors, energy harvesting, and activity and behavior recognition. These are described in the following section.[1]

Reusable results One of the key requirements for the project is that sensors have to be installed not only in new buildings, but in existing ones too. Considering the initiatives that have been reviewed, this constraint is well addressed by SM4All, ThinkHome, SEEMPubS (existing public buildings), Bode, iSpace, eDIANA, E3SoHo, HYDRA, Thermco, EcoSense, Enprove (tools to incorporate in existing buildings and management systems), Hospilot, IntUBE, SportE2, TIBUCON, HOMES (existing and new buildings) and PEBBLE. Even though the other projects are not clearly stating that they can incorporate the technology into existing buildings, as soon as they deploy wireless technology,

[1]Refer to the DOW in Section "B.1.1.4 Quantified objectives and outcomes" for more details on Objective 1.

we can assume this is possible.

Minimal installation procedures and maintenance is achieved through the use of wireless technology or by using existing wired infrastructure of buildings. Wireless technology is used by SM4All, BeyWatch, Smart Houses Interacting with Smart Grids to achieve next-generation energy efficiency and sustainability (SmartHouse/SmartGrid), Aura (wireless infrastructure deployment), eDIANA (wireless infrastructure for fast and cost-effective deployments), SOFIA (smart spaces will interact with wireless devices), HYDRA, EcoSense, OPPORTUNITY, Enprove (WSN sensing infrastructure), Aware-Home, Dehems (using existing WSN technologies), Hospilot, Sensei (wireless sensor and actuator network), TUBICON (low-power WSN). In the case of existing wired infrastructure, project that make use of it are Intelligent Buildings, BeyWatch, HYDRA, EcoSense. Also, projects House-n and PEBBLE addresses minimal installation efforts through easy to deploy sensors, interfaces and devices, regardless of the type of underlying communications infrastructure.

Another important target outcome deals with the physical location of sensors. Optimal location is needed in order to have a more efficient sensing system. The initiatives that deals with the optimal physical location are: Development of a Testbed for Wireless Sensor Networks in Building Automation Projects (predict allowable spacing between adjacent wireless communication points), Aura (large-scale deployment needs to take into account the strategic placement of sensors), House-n (hundreds of sensing components installed nearly in every part of the home), SOFIA (smart space formed by sensors and devices with self-organizing capabilities), and Sensei (large-scale deployments).

Regarding activity recognition and behavior detection in buildings, the following project addresses them: ThinkHome (artificial intelligence, identify users and buildings current situation), SEEMPubS (context awareness, user awareness and interaction), Development of a Testbed for Wireless Sensor Networks in Building Automation Projects (user activity, building utilization and context), BeyWatch (context retrieved by user input), Smart Houses Interacting with Smart Grids to achieve next-generation energy efficiency and sustainability (perform savings based on user needs), Aura (locations of users, availability of printers and available bandwidth. Aware of what users are doing), Amigo (services based on user activity), House-n (human behavior and how they act in presence of technology, recognize life patterns), Bode (camera network, estimate occupancy), iSpace (intelligent gadgets that can detect occupants behavior), SOFIA (ontologies to provide a model for smart spaces), Persists (platform makes context information available to interested parties, learning and reasoning about users, context semantics and location-based criteria), Thermco (simulations and building models), Casas Project (activity of occupants, recognition and context of the house), EcoSense (network used to infer the context of the building through temp., light and humidity), OPPORTUNITY (mobile systems to recognize human activity and user context with dynamically varying sensor setups, using goal oriented, and cooperative sensing), Enprove (Monitoring building usage can be seen as looking at users, in particular user behavior), Aware Home (creating a home environment that is aware of its occupants whereabouts and activities), Dehems (energy performance model that also looks at the way in which the energy is used), Sensei (reliable and accurate context information retrieval and interaction with the physical environment), 3e-Houses, BeAware (integrate awareness cues through mobile and ambient interfaces into consumers everyday lives taking into account cognitive capabilities and social practices), and PEBBLE (taking into account human factors and adapting the decisions in, occupant actions and activities influence the thermal behavior of buildings).

Energy harvesting is considered important for GREENERBUILDINGS. There are only few initiatives that takes this into account: TIBUCON (Development of hybrid indoor energy harvesting units for powering self powered wireless sensors) and HOMES. As TIBUCON is a recent project, there are no other details or deliverables with more information about the outcomes regarding this section. The HOMES technology however, is indeed potentially applicable to GREENERBUILDINGS.

An overview of all these considerations is provided in Table 3.1. The relevant reviewed initiatives that contribute to each of the target outcomes of Objective 1 are indicated.

GREENERBUILDINGS' contribution GREENERBUILDINGS will utilize existing standards and concepts for sensor and actuator interfaces as the GREENERBUILDINGS framework will be adaptable to various existing building infrastructures. Hence, it will not be the focus of GREENERBUILDINGS to develop a wide variety of sensor nodes or actuator interfaces, but rather to fill gaps. Such gaps are expected to be identified from the simultaneous consideration of activity and behavior information processing and the required sensor input.

GREENERBUILDINGS will benefit from outcomes of the initiatives related to context-awareness and low-cost technology and maintenance procedures. Primarily, reuse is expected for sensor node and actuator families that use common protocols (e.g. EnOcean, IEEE 802.11.4, etc.). The major contributions could come from incorporating large-scale deployments for more accurate estimations on users and buildings behaviors.

On the other hand, little contributions are in the field of energy harvesting, giving GREENERBUILDINGS good opportunities to make progress and investigate suitable technologies to help powering devices and minimizing maintenance efforts.

3.2 Objective 2, Activity & context inference

Objective 2 of GREENERBUILDINGS addresses the development of algorithms to infer occupant behavior and building context knowledge from spatially distributed sensors. It is stated in the DOW as follows: “To complement noisy and weak information from individual sensors activity recognition requires robust pattern recognition and context inference techniques that combine multimodal sensing sources and adequate modeling. Behavior and building context information must be analyzed for its relevance on energy conservation."[2]

Reusable results Several projects among the reviewed initiatives address context and activity recognition in some form. However, none targets the integration of occupant activity and contextual knowledge extraction from buildings in order to improve energy efficiency.

The following initiatives provide useful results for GREENERBUILDINGS regarding activity and context recognition, as these use actual sensors to retrieve information from the environment. Initiatives that address context and activity recognition are:

- **Intelligent Buildings (Section 4.2):** uses location information by deploying an active badge system in office buildings.
- **Aura (Section 4.8):** is a ubiquitous computing framework that does not emphasize energy efficiency.
- **House_n (Section 4.10):** uses ambient and on-body sensing infrastructure mainly to monitor lifestyles and habits.
- **Bode (Section 4.11):** uses camera solutions to build occupancy models.
- **Casas Project (Section 4.22):** investigates activity recognition in smart homes to provide input for several control and intervention purposes, e.g. to detect anomalies, need for robotic interventions, and estimate energy usage.
- **Opportunity (Section 4.24):** uses opportunistic sensing approaches for activity recognition. The project emphasizes the support of dynamically varying sensor networks.
- **Pebble (Section 4.36):** uses activity recognition methods to make intelligent decisions regarding building adaptations, primarily for energy harvesting buildings. Mostly low-level cues such as opening windows and operating user interfaces are considered as information input.
- **HOMES (Section 4.37):** uses presence information to adapt building spaces. However, no further activity and behavior information was used.

Of these initiatives, only the Pebble project focuses on a goal closely related to GREENERBUILDINGS. However, the approach in Pebble differs from GREENERBUILDINGS, as activity recognition is performed via switches and user interfaces only. In contract, GREENERBUILDINGS incorporates a multi-modal approach with continuously streaming sensors that provide fine-grained activity and behavior information. Moreover, Pebble focuses on positive-energy buildings, hence buildings that produce more energy

[2]Refer to the DOW in Section "B.1.1.4 Quantified objectives and outcomes" for more details on Objective 2.

than they require. This does not apply for many existing and new built large-scale buildings, such as offices. A collaboration with Pebble on activity recognition topics could however be well incorporated in GREENERBUILDINGS.

Intelligent Buildings uses an intrusive technique to localize users (requiring occupants to wear batches), which could remain a critical issue for the acceptance in public buildings. However, the information processing using a multi-agent system is interesting. Using statistical techniques to model occupancy of spaces over time as done in Bode is an interesting possibility to predict occupancy. House_n monitors their users intensively, but uses this data for other purposes than energy efficiency.

Several of the reviewed initiatives focused on monitoring and interpreting environmental conditions (context recognition). Although these initiatives did rarely address user requirements at a specific moment, the utilized approaches could possibly be reused in GREENERBUILDINGS. These initiatives are:

- **iSpace (Section 4.12):** investigates an installation in a single room, where a number of 'smart objects' are used to remember user preferences. The smart objects are able to turn on lights or heating, for instance.
- **EcoSense (Section 4.23):** aims at large scale building installations, where decisions are primarily based on environmental conditions (temperature, light conditions and humidity).
- **EnProve (Section 4.25):** targets a detailed assessment of energy usage, and subsequently predict energy usage for the future.

Another group of initiatives focused on supporting context and activity information extraction in a processing framework. However, the actual recognition step was not a development priority. These initiatives include: SM4All (Section 4.1), Amigo (Section 4.9), Persist (Section 4.17), and Aware Home (Section 4.26).

GREENERBUILDINGS' contribution Research on context and activity recognition is ongoing. The combination of contextual knowledge and energy efficiency in public buildings is still not sufficiently addressed to determine its benefit. Moreover, many approaches focus on either on user activity or building context recognition. Hence, GREENERBUILDINGS can make profound novel contributions, as the project incorporates context and activity information to make buildings more energy efficient and adapt buildings to occupant comfort needs simultaneously. Furthermore, GREENERBUILDINGS will evaluate the developed solutions in large scale living-lab installations. GREENERBUILDINGS will build on results and methods of House_n and Opportunity, as these projects specifically focused on living-lab analysis and activity recognition methods.

3.3 Objective 3, Energy-aware service-based middleware

This section relates to an open and extensible framework and architecture to autonomously adapt building operation. Objective 3 of GREENERBUILDINGS is described as: “The framework must be compatible with a scalable architecture of sensing, processing, and actuation devices that are operated in a largescale heterogeneous network. A myriad of adaptable (smart) building appliances exists today and is partially installed in buildings already. The infrastructure has to cope with multiple standards and proprietary protocols to interface with smart appliances, building installation, other buildings, and the smart grid. Finally, the measures must be taken to sustain the project results in the long term.”[3]

3.3.1 Composition

Reusable results Service-based middleware is clearly gaining momentum in the area of ubiquitous computing, though most initiatives of the past only consider this type of middleware to address device association and interoperation issues. With few exceptions, e.g., SM4All and Hydra, the paradigm of service-orientation is not lifted to the application level. Furthermore, the energy awareness aspects seem to be transversal with the service-orientation of the middleware, thus being more of a subsequent concern/add-on rather than a primary design concern of the middleware. With respect to these aspects, the experience on using service-oriented middleware in ubiquitous settings are definitely useful for GREENERBUILDINGS and can form the foundation for the design of an energy specific middleware. In particular, from the point of view of composition we remark how SM4All (Section 4.1) uses Artificial Intelligence (AI) planning techniques for service composition. Intelligent Building (Section 4.2), ThinkHome (Section 4.3), SEEM-PubS (Section 4.4), BODE (Section 4.11), iSpace (Section 4.12), and CASAS (Section 4.22) provide ideas on how to apply knowledge base ontology and multi–agent system as well as control strategies when designing composition layer. At the same time, in EcoSense (Section 4.23) the agents are used for goal management and task execution. Aura (Section 4.8) framework is able to do various simple tasks, e.g. checking whether services are available, sending messages and email to other people’s Aura. On the other hand, PERSIST (Section 4.17) delivers the prototype Learning and Reasoning Systems and a prototype for Pro–active Behaviour Systems. Meanwhile, the applications run on POBICOS (Section 4.18) middleware are provided mechanisms to find, combine, and exploit proper resources of the object community. IntUBE (Section 4.33) defines a service platform that can be seen as the integrating common software infrastructure for relevant software applications (CAD, energy calculation/simulation, monitoring, controlling, etc.) and/or services.

[3] Refer to the DOW in Section “B.1.1.4 Quantified objectives and outcomes” for more details on Objective 3.

The use of semantic annotation techniques and of the paradigm of Multi–Agent modelling are often used in the literature. These are related to the concept of service-composition, though not exactly the same. Such experiences are thus valuable for GREENERBUILDINGS especially as a benchmark to see what levels of efficiency have been already reached with these approaches.

GREENERBUILDINGS' contribution Service-based middleware is a relatively recent concept and few proposals exists integrating energy awareness. Of these, most of them are concerned with large data-centers and cloud computing facilities. Furthermore, the practical experiences are quite limited. In addition, most proposals on using services based middleware consider services as low level basic operations (e.g., Jini). Some preliminary ideas have been proposed in SM4All in reusing the service based middleware for home energy saving, but this is seen as a possible application of the middleware. Also the scalability of such an approach from one home to an entire building is all to be proven and may even be questionable. Therefore, with GREENERBUILDINGS we propose to go one step further in the design and implementation of the service-based middleware focusing on the following specific aspects: energy-aware dynamic service composition (novel design w.r.t. state of the art) that can handle thousands of instances (improved scalability w.r.t. state of the art) and can deal with conflicting goals of users (thus able to deal with concurrency of compositions and compositions with conflicting and inconsistent goals).

3.3.2 Orchestration and scheduling

Reusable results To the best of our knowledge, among all the initiatives reviewed in Chapter 4, we have identified a subset of them following a service oriented approach. In particular, among all, we can cite SM4All, SmartHouse/SmartGrid, Amigo, SOFIA, HYDRA, Enprove, Dehems, Hospilot and Sensei. However, from the information collected, it is not always clear if an orchestration phase or a scheduling procedure is defined. Only SOFIA and Hospilot consider explicitly an orchestration phase to provide complex services. In particular, SOFIA uses orchestration to let a smart space able to provide complex services and composite data to the external world, while Hospilot uses orchestration to let basic building blocks cooperate with the specific goal to optimize energy consumption in hospitals.

GREENERBUILDINGS' contribution In GREENERBUILDINGS we can follow SOFIA's approach for the orchestration by defining complex services starting from basic ones with the final goal of energy saving (as in Hospilot). Moreover, considering the autonomous characteristic of the GREENERBUILDINGS vision, we should take into account the possibility that several entity can require, concurrently, the execution of a complex service (i.e. an orchestrated service). To this aim, we have to consider the definition of a scheduling engine able to manage concurrent requests for complex services execution.

3.4 Objective 4, Quantitative evaluation of effectiveness and economic impact

As stated in the DoW[4], the impact both in economic terms and in energy saving terms needs to be analyzed. Existing strategies and technologies that save energy must be analyzed in different building and usage settings to provide quantitative conclusions for design and implementation of GREENERBUILDINGS solutions. In this context, similar initiatives with goals related to cost-effective energy saving in buildings will provide useful results as a benchmark to GREENERBUILDINGS solutions (note that we do not consider initiatives related to *residential* energy saving solutions to be in scope at this point since the domain is rather different to expected solutions for large-scale buildings). Moreover the sharing of relevant usage data and methodologies to measure building energy usage, comfort and occupancy behavior and control across currently running projects is also seen as a very important follow up to this analysis.

Reusable results From a smart-grid perspective, initiatives such as SEEMPubs advanced metering infrastructure and REViSiTE could provide a useful touch point with the envisioned GREENERBUILDINGS architecture, since it also focusses on large spaces where many users are present. The projects Bode, HOMES, and EnPROVE projects will likely offer useful insights with respect to occupancy behavior and energy consumption prediction. Also since the some of the scope of eDIANA includes large buildings too for energy optimization, their results regarding their cell architecture for energy sensing as well as strategies for providing user feedback and control can provide useful quantitative input for the GREENERBUILDINGS system requirements.

The Thermco, Pebble and TIBUCON projects will likely provide valuable data regarding low energy heating and cooling models (e.g. their studies on thermal comfort) that can be used within the GREENERBUILDINGS solution. The EcoSense project may provide useful recommendations for how to deploy low cost solutions in the field. The Hospilot project has similar facets with GREENERBUILDINGS (although their focus is exclusively on hospitals), that may also provide some insights into quantifying the potential energy savings and cost reductions (include ROI) that become possible through the addition of building intelligence. Also, part of the IntUBE project results that relate to office buildings will also help service the requirements phase of GREENERBUILDINGS with respect to quantifying user comfort with respect to different energy profiles.

GREENERBUILDINGS' contribution Many of the projects cited above can be considered complimentary to the GREENERBUILDINGS technology offering when evaluating the economic impact and effectiveness of the smart energy solutions. For example, shar-

[4]Refer to the DOW in Section "B.1.1.4 Quantified objectives and outcomes" for more details on Objective 4.

ing of measured and modeled data will be useful to all parties whose building-domain focus overlaps. However, all of these projects do not share the same focus as GREENERBUILDINGS regarding the activity and behavior-centric aspects that encompass both user comfort and energy saving possibilities.

Moreover, the ability for users to customize their comfort and energy saving needs based on their activities and goals within large buildings can be argued to be a unique approach that adds to the results offered by the cited projects (e.g. it extends the paradigm introduced in the eDIANA project regarding end-user control). The use of living-labs to quantify the impact of these approaches is therefore important in order to benchmark techniques to the outcomes of related initiatives. Experience gained in other projects that utilized living-labs will thus be important learnings for the successful implementation in GREENERBUILDINGS. In particular, GREENERBUILDINGS will aim to establish contacts to projects that can provide insight or potential sharing options of living-labs, e.g. EnProve.

3.5 Objective 5, Quantitative evaluation of user experience

The purpose of Objective 5 is to evaluate which result is focused on the user experience in terms of occupant satisfaction and productivity. In this context building thermodynamic is a crucial aspect, especially to maintain comfort and productivity of occupants; in GREENERBUILDINGS both experimental and simulation approach will be used taking into account the indoor parameters but also weather and important outdoor variables, hence we must here consider what is reusable in terms of environment simulations, physical measurements and occupant behavior simulations.[5]

Reusable results Some initiatives/projects in this review show useful elements and the reusable results with the related initiative have been summarized below.

- **Thermco (Section 4.21)** important elements are reusable: Occupant Satisfaction Analysis (relevant results on the importance of comfort parameters related to occupant satisfaction), thermal-fluid analysis in different European buildings and scenarios, results on different environment and considerations related to adaptations (e.g. ventilation, thermal efficiency).
- **Casas Project (Section 4.22)** the activity recognition and visualization code (AV Code, AR Code) can be a role in the simulation of the environment, especially when the occupant and the activities are taken into account, with the aim to evaluate the

[5] Refer to the DOW in Section “B.1.1.4 Quantified objectives and outcomes” for more details on Objective 5.

user experience related to thermal aspects inside both the preliminary phase and the real-time buildings simulations.

- **EcoSense (Section 4.23)** the method for the measurement devices deployment for the indoor environment and the measure of the external parameter can be reuse into the living lab analysis, especially for the integration into the simulations.
- **TIBUCON (Section 4.35)** in the project the SP-MM-WSN technology has been used in building thermal condition monitoring allowing thermal simulations of the heating system and the comparison with the data from the sensors.
- **PEBBLE (Section 4.36)** in the PEBBLE System the building responds with respect to external (weather) and internal (user) excitations, according to dynamics prescribed by the building construction, with controllable elements that operate according to the decisions taken by the system. An important element is accurate and efficient simulation models that incorporate all passive, active and energy-generation elements and, given local weather data and weather prediction models, can be used to predict thermal response, energy requirements, and estimate user comfort.

GREENERBUILDINGS' contribution The elements about quantitative evaluation of satisfaction and awareness of occupants have not received exhaustive attention in the identified projects. Moreover, maintenance of energy saving policies are not sufficiently implemented in the analyzed projects. Only a few projects (Thermco, Intelligent Buildings) addressed these issues.

Thus, GREENERBUILDINGS will have an important role regarding the analysis of occupant experience: the opportunity to evaluate this aspect in actual installations over extended time periods is very useful to estimate the system adaptation with occupant activity. Ways to continuously incorporate occupant feedback in the living-lab settings will be an essential factor to incorporate satisfaction in the control process.

3.6 Summary

The reviews showed that GREENERBUILDINGS can relate to a number of previous and on-going efforts and standards and at the same time, make substantial contributions towards energy-efficient public or semi-public buildings. As a main result of the review, the focus on activity and behavior recognition principles and their use for energy efficiency in public buildings has been strengthened. As incorporating activity and behavior recognition is a unique aim of GREENERBUILDINGS, it will enable the project to provide substantial novel contributions to energy-efficient buildings.

The main areas in which GREENERBUILDINGS can reuse results are:

- Sensor and wireless solutions for large-scale deployments in buildings.

- Standard interfaces for interconnection and interoperable sensors and actuators, e.g. based on EnOcean, IEEE 802.11.4, etc.
- BMS infrastructure (where sufficiently established) for sensing and actuation, and access to relevant contextual and environmental information.
- Context and activity recognition methods based on on-body and ambient sensing.
- Proposals on scalable service-based middleware solutions.
- Defining complex building services for energy-adaptive operations starting from basic ones.

Areas that GREENERBUILDINGS will make novel contributions on top of the state-of-the-art are:

- Energy efficient and energy harvesting sensor nodes for selected applications in ambient context and activity recognition. The focus is here to fill gaps that appear through the simultaneous consideration of activity sensing and processing aspects, and not to provide further generic solutions.
- Fusion of multi-modal and distributed context and activity recognition information in large scale installations. In particular, GREENERBUILDINGS can leverage from living-lab installations specifically addressing the activity recognition challenge.
- Design and implementation of service-based middleware that can sufficiently scale and is robust enough for the use in large scale buildings.
- Concurrent execution of complex services that may imply contradictory goals.
- Evaluating user activity and sensor placement with thermo-fluid dynamics building simulations.

Initiative	Section	Target Outcomes of Objective 1				
		Sensors have to be integrated in existing buildings	Minimal installation and maintenances	Strategic and optimal physical location of sensors	Energy Harvesting	Activity and behavior detection
SM4All	4.1	*	*			
Intelligent Buildings	4.2		*			*
ThinkHome	4.3	*				*
SEEMPubS	4.4	*				*
Development of Testbed for WSNs ...	4.5			*		*
BeyWatch	4.6		*			*
SmartHouse/ SmartGrid	4.7		*			*
Aura	4.8		*	*		*
Amigo	4.9					*
House_n	4.10		*	*		*
Bode	4.11	*				*
iSpace	4.12	*				*
eDIANA	4.14	*	*			
SOFIA	4.15		*	*		*
E3SoHo	4.16	*				
Persists	4.17					*
HYDRA	4.20		*			
Thermco	4.21					*
Casas Project	4.22					*
EcoSense	4.23		*			*
OPPORTUNITY	4.24		*			*
Enprove	4.25		*	*		*
AwareHome	4.26		*			*
Dehems	4.27		*			*
Hospilot	4.29	*	*			
Sensei	4.30		*	*		*
3e-Houses	4.31					*
BeAware	4.32					*
IntUBE	4.33	*				
SportE2	4.34	*				
TIBUCON	4.35	*	*		*	
PEBBLE	4.36	*	*			*
HOMES	4.37	*	*	*	*	
SCUBA	4.37					
ALwEN	4.39					

Table 3.1: Sensor characteristics focus of different initiatives in relation to GREENER-BUILDINGS. The relevant initiatives are valued with respect to the target outcomes of Objective 1.

Chapter 4

Initiatives

In this chapter all the initiative reviews are presented. Each section discusses the initiative in five parts and the criteria matrix that describes how this initiative relates to GREENER-BUILDINGS.

4.1 SM4All

4.1.1 Abstract

The SM4ALL [owpk] (Smart hoMes for ALL) project aims at studying and developing an innovative middleware platform for the inter-working of smart embedded services in immersive and person–centric environments, through the use of composability and semantic techniques, in order to guarantee dynamicity, dependability and scalability, while preserving the privacy and security of the platform and its users.

The SM4ALL project's goal is that of defining and developing an embedded pervasive platform for smart houses truly for all, in which users with different abilities and needs can interact with the services provided by the different domotic devices, appliances and sensors through basic and advanced interfaces, being the latter ones based on brain-computer interaction technologies.

The SM4All project is funded by the European Commission, within the Seventh Framework Programme. It started in September 2008 and has a time frame of 36 months.

4.1.2 Goals

The goal of the SM4ALL architecture is to seamlessly integrate devices in order to simplify access to services provided by home devices and dynamically compose their services to offer to the end users more complex functionalities and a richer experience of the do-

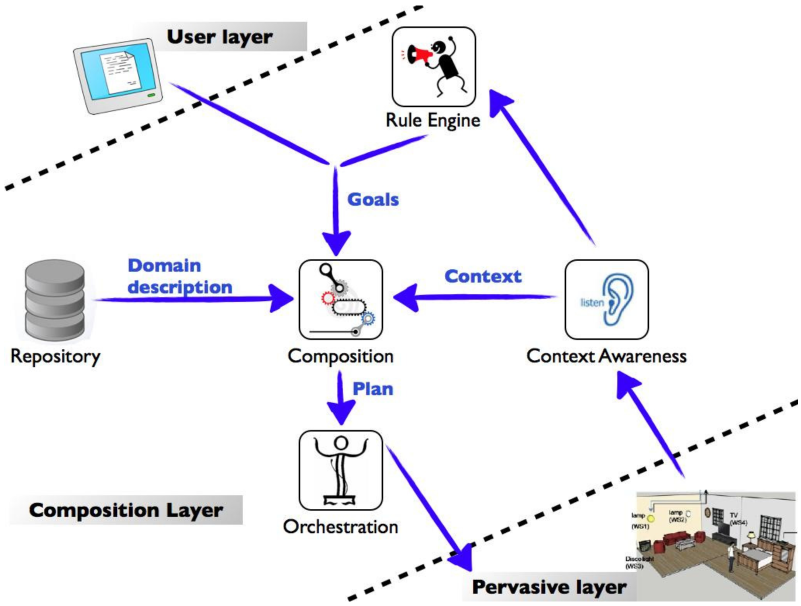


Figure 4.1: SM4All System Architecture

motic environment.

The ambitious target of the SM4ALL project is to couple, for the first time, advanced research and techniques in embedded and distributed systems with service oriented computing and accessibility and advanced interaction techniques, thus developing a truly embedded dynamic environment for all.

4.1.3 Approach

The project designs, implements and evaluates a generic Service–Oriented Architecture (SOA) for homes which supports highly dynamic computing context.

The SM4All architecture for a domotic application uses the concept of a service as its fundamental abstraction. The architecture distinguishes between a pervasive layer where devices and their basic inter–networking live, and a composition layer where services can be dynamically composed to react to user desires or home events on top is the application or user layer which provides the interface to the home, using touch screen and brain computer interface.

From the technical point of view, the implementation uses UPnP as the basic device connection protocol and techniques from Artificial Intelligence planning for composing at execution time services on behalf of the user and the home. A description of the whole system is illustrated in Figure 4.1.

- **User layer:** is devoted to the interaction of the middleware with final users and administrators. This interaction is realized through various User Interfaces (UIs).

- **Composition layer:** Logical components contained in the composition layer have the main goal of receiving high level commands issued by users through the interface layer and fulfilling the corresponding complex goals by controlling the execution of lower level services offered by devices deployed within the SM4ALL architecture.

- **Pervasive layer:** The SM4ALL pervasive layer aims to interconnect devices in heterogeneous networks in the home and to provide a common mechanism for accessing the services they offer. The pervasive layer is a highly asynchronous software layer based on the concept of event. This layer is constituted by a single logical component called Discovery Framework. It is responsible for letting physical devices interact with the upper layer components by publishing available service descriptors, executing service instances, decoupling interactions from the specific communication mediums, etc. This component realizes an abstraction layer wrapping all of the devices currently in the house.

4.1.4 Outcomes

The expected outcomes of the project are:

1. Embedded middleware platform for person-centric environment.
2. Novel scientific techniques for data dissemination, service composition, dependability, scalability, security and privacy preservation.
3. Seamless compatibility among different communication standards (WiFi, ZigBee, Bluetooth, etc.)
4. Support composability, scalability and minimal power consumption while offering open interfaces to third parties for application development.
5. Develop basic (web interface) and advanced interfaces Brain Computer Interaction (BCI).
6. Discovery of new devices
7. Management of failures and support for dynamic removal of devices

4.1.5 Relation to GREENERBUILDINGS

GREENERBUILDINGS can take advantage of the SM4All composition layer and pervasive layer in the areas of middleware and service composition approaches as well as system architecture.

- **Middleware & compositional approaches:** SM4All uses Artificial Intelligence (AI) planning techniques for service composition, and UPnP as the basic protocol for interoperation. The SM4All middleware abstracts from distribution, providing a coherent application interface. In the case of the Smart Home, the middleware is a layer that has to offer a number of services to the participating components. It has to accommodate for dynamic group membership, asynchronous communication, provide a common message ontology, support heterogeneous and mobile devices, and the mobility of the user.

- **System architecture:** SM4All designs and implements a software architecture based on the concept of service, that supports the integration of heterogeneous home devices, the inference of the home context, and the possibility to compose services inside the home as a response to a user need or a home event.

- **Building automation & operational services:** SM4All's pervasive layer has a dynamic discovery framework and pervasive controller to connect heterogeneous devices and exposes the devices' services to upper layers. SM4All uses standardized technologies, namely, UPnP as the protocol for the direct access to hardware services, Web service based WSDL and SOAP protocols to expose high level services, and OGSi as the wrapping layer bridging UPnP and Web service level service invocations.

  The pervasive layer is a highly asynchronous software layer based on the concept of event. The central point of control enables the pervasive layer to be extended with features that are integral parts of a middleware systems such as concurrency management and security.

- **Sensors & wireless technology:** Interestingly, WiFi, ZigBee, and Bluetooth are taken into account of SM4All discovery framework. WiFi, ZigBee, and Bluetooth devices are integrated seamlessly into the system.

- **Context & activity recognition:** Moreover, in the composition layer, there is *context awareness* module responsible for the collection of the sensed information from the home, and the maintenance of a representation of the execution and user context in the home, by reading information directly from the pervasive layer

The relations of SM4All to GREENERBUILDINGS are summarized in Table 4.1.5

4.2 Intelligent Buildings

4.2.1 Abstract

"Intelligent Buildings" [wpc] is a project which aims to develop agent-based approaches for distributed monitoring and control of office buildings. The objectives are both energy

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency						
Scalability			Context–awareness	AI planning techniques, Dynamic PDF, semantic repository	Middleware layer/sm4all architecture	
Privacy						
Costs						
User comfort						
Adaptability				Pervasive layer		
System reliability						
Data security						
Dynamicity				Pervasive controller/layer		
Standard Compliance					UPnP, OSGi	WiFi, ZigBee, and Bluetooth

Table 4.1: SM4All relations

saving and increasing customer satisfaction through value added services.

The project was led by the Swedish Institute of Computer Science (SICS), Royal Institute of Technology from 1997 to 2005.

4.2.2 Goals

The system consists of a Multi-Agent System (MAS) that monitors and controls an office building. It uses the existing power lines for communication between the agents and the electrical devices of the building, i.e., sensors and actuators for lights, heating, ventilation, etc. The objectives are both energy saving, and increasing customer satisfaction through value added services.

Energy saving is realized, e.g., by lights being automatically switched off, and room temperature being lowered in empty rooms. Increased customer satisfaction is realized, e.g., by adapting temperature and light intensity according to each person's personal preferences.

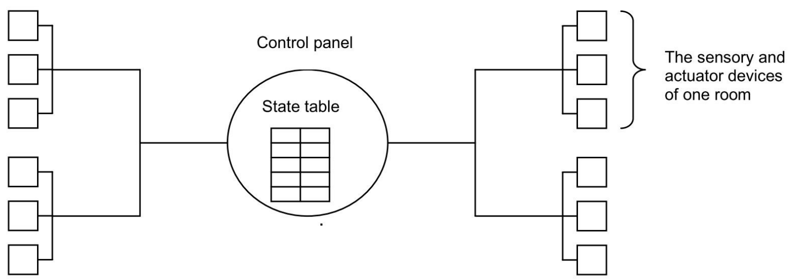


Figure 4.2: The Hardware Infrastructure of Intelligent Buildings

4.2.3 Approach

The main focus of the project is to apply and develop Multi-Agent approaches to distributed monitoring and control of office buildings [DB98, DB05].

A building contains a number of electrical devices that constitute an important part of the infrastructure of the building. Each electrical device (i.e., sensors and actuators for lights, heating, ventilation, etc.) in the system is connected via special purpose hardware nodes to a system based on LonWorks technology [wpd], allowing the exchange of information over the electrical network. An active badge sensor is used for identification and localization of people. All the information received from the devices is recorded centrally and accessible on a control panel as illustrated in Figure 4.2.

Devices interact with, and are controlled by, the MAS. The interaction is mediated by the control panel. An interface translates messages originated from the MAS to commands understood by the LonWorks system and vice versa.

The Multi-Agent System: A multi-agent approach is adopted during the design and implementation of the software. Each agent corresponds to a particular entity of the building, e.g., office, meeting room, corridor, person, or electrical device. Agents are given a number of rules which express the desired control policies of the building conditions. The occurrence of certain events inside the building (e.g., a person moving from one room to another) will generate messages to some of the agents that will trigger some appropriate rule(s). The agents execute the rule(s), with the purpose to adjust the environmental conditions to some preferred set of values. The rule will cause a sequence of actions to be executed, which will involve communication between the agents of the system. For the format of the messages a Knowledge Query and Manipulation Language (KQML) [owpe] like approach is followed.

There are four main categories of agents in the MAS:

1. *Personal Comform (PC) agent* corresponds to a particular person.
2. *Room agent* corresponds to and controls a particular room with the goal of saving

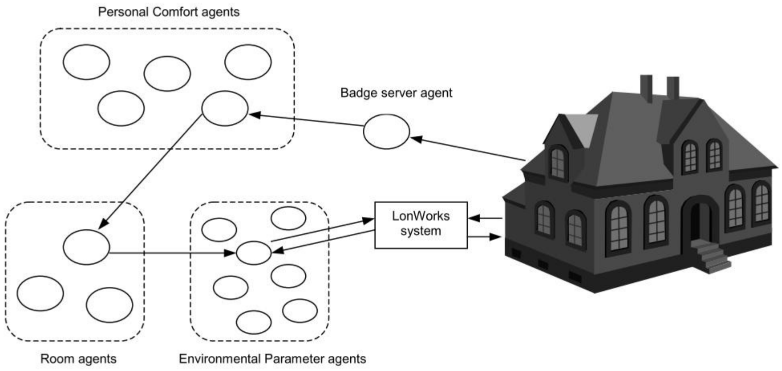


Figure 4.3: The Multi–Agent System of Intelligent Buildings

as much energy as possible.

3. *Environment Parameter (EP) agent* monitors and controls a particular environmental parameter in a particular room.

4. *Badge System Agent (BSA)* keeps track of where in the building each person (badge) is situated and maintains a data base of the PC agents and their associations to persons (badges).

For conceptual and administrational purposes the agents have been divided into three groups, see Figure 4.3.

The PC agents may reside on the individuals' desktop computers and interact locally with the corresponding person, e.g., in order to change the preferences. Normally, the preferences are set when the agent is initiated, i.e., when the person visits the building for the first time, and rarely changed. When a person movement is detected (movement from one room to another in the building or movement into/out of the building) the BSA informs the appropriate PC agent about this movement. In addition, other agents may query the badge server agent in order to get hold of this information.

When a PC agent is notified that its corresponding person has moved to another room, it informs the appropriate room agents, i.e., the agent of the room the person is leaving and the agent of the room the person is entering. The PC agent also provide the room agent with the personal preferences. The room agent decides, based on these preferences and on energy saving considerations, the new desired environmental conditions and pass them on to the EP agents. The EP agents then pass them on to the control panel via the interface described in the previous section.

4.2.4 Outcomes

Multi–agent system architecture was fully built and evaluated with some basic simulations of the building environment [DB98, DB00b, DB05, DB00a].

4.2.5 Relation to GREENERBUILDINGS

The Intelligent Building project has very similar objectives to GREENERBUILDINGS aiming at energy saving and increased personal comfort. The areas relate to GREENERBUILDINGS are mainly the possibility of applying MAS at the Composition layer and using active badge to localize the positions of persons in buildings.

In particular, the following results of "Intelligent Buildings" could be exploited:

- **Context & activity recognition:** The application of active badge technique for localizing persons.
- **Middleware & compositional approaches:** The application of MAS into the architecture of Composition layer. A multi-agent approach is adopted during the design and implementation of the software. Each agent corresponds to a particular entity of the building, e.g., office, meeting room, corridor, person, or electrical device. Agents are given a number of rules which express the desired control policies of the building conditions.
- **System architecture:** Each electrical device in the system is connected via special purpose hardware nodes to the LonWorks system, allowing the exchange of information over the electrical network.

The relations of Intelligent Buildings to GREENERBUILDINGS are summarized in Table 4.2.5.

4.3 ThinkHome

4.3.1 Abstract

ThinkHome [wpf] proposes the intelligent home of the future that utilizing artificial intelligence (AI) to improve control of home automation functions provided by dedicated automation systems. It is able to detect and utilize patterns to provide a better, more energy-efficient, yet comfort oriented, control of building functions.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency						
Scalability				Multi–Agent System	Multi–Agent System	
Privacy						
Costs						
User comfort			Active Badge			
Adaptability			Active Badge	Multi–Agent System		
System reliability						
Data security						
Dynamicity			Active Badge	Multi–Agent System		
Standard Compliance	LonWorks					

Table 4.2: Intelligent Buildings relations

4.3.2 Goals

ThinkHome is designed under two main premises: it shall ensure energy efficiency and comfort optimization.

Primary targets are functions that require comparably high amounts of energy, such as those found in heating/ventilation and air–conditioning, and lighting/shading. For an optimization, the system must be capable of detecting user interactions and desires, to identify patterns in these data and to be able to learn and adapt to its environment. ThinkHome must therefore be able to perceive its environment, especially the home in which it is employed. It has to learn environmental parameters such as thermal inertia and combine this knowledge together with various parameters and data found in and around today's buildings (presence, occupancy, temperature, daylight...) to find an optimal strategy for controlling the environment.

4.3.3 Approach

ThinkHome architecture features two main parts, a comprehensive knowledge base (KB) and a multi–agent system (MAS). These concepts are applied in a intelligent, energy–efficient home. A detail explanation of KB and MAS can be found in [RKIK11].

ThinkHome aims at the realization of an intelligent home by introducing semantic context and artificial intelligence (AI) in this future home. The AI here is realized by means of control strategies that are embedded and cooperate fairly within the highly interoperable ThinkHome system structure that provides transparent access to data, users, building systems, and miscellaneous other services. It is able to detect and utilize patterns to provide a better, more energy-efficient, yet comfort oriented, control of building functions. The focuses are:

- The AI–based control strategies that allow maximizing energy efficiency: In order to maximize the usefulness of AI, different approaches have to be investigated and evaluated regarding their performance and output when both energy efficiency and user comfort are taken into account.
- An agent based framework that has the artificial control strategies embedded is home for agents acting on behalf of users (avatars).

The comprehensive ThinkHome approach also considers two aspects frequently forgotten in other systems: a usable interaction between the system and its users and an unobtrusive yet ubiquitous integration of the smart system in the daily context.

The project proposes a system architecture built on a knowledge base that achieves the integration of previously unconsidered information.

ThinkHome project also implements a knowledge base ontology that stores all information needed to fulfill the goals of energy efficiency and user comfort. Then, the comprehensive knowledge storage is complemented by a multi-agent system, that finally uses all the stored knowledge to realize a more energy efficient building operation.

4.3.4 Outcomes

The main outcomes of the project are in the areas of Service Composition and Multi–Agent System application [RKIK11, KKR10, RKK10].

1. Knowledge Base Ontology: the division of a domain into relevant concepts and its formal representation is known as ontology. In ThinkHome, it is represented with Web Ontology Language (OWL), enabling intelligent decision making.
2. Multi–Agent Framework: Methods from AI are employed, realizing optimized control strategies that allow maximizing energy efficiency and user comfort simultane-

ously and automatically. In ThinkHome, the main task of Multi–Agent System is to realize advanced control strategies.

3. Control Strategies: The control strategies are the core part of the intelligent operation of a ThinkHome building. They are responsible for the calculation of all actions (switching commands, start/stop times and many other parameters) that are executed by the underlying building automation systems.

4.3.5 Relation to GREENERBUILDINGS

GREENERBUILDINGS can take advantage of knowledge base ontology and multi–agent approach from ThinkHome when designing the system. In particular, the following results of "ThinkHome" could be exploited:

- **Context & activity recognition:** In ThinkHome system, *Context Inference Agent* is responsible for identifying activities and building a model of the current situation while emphAuxiliary Data Agent is used to integrate additional data from miscellaneous sources, for example, from Internet–based web services. At the same time, *User Agent* provides user's preferences.
- **Middleware & compositional approaches:** The project provides ideas on how to apply knowledge base ontology and multi-agent as well as control strategies when designing composition layer.
- **System architecture:** The project provides ideas on designing an open system, that (inter)operates on open standards and open software and provides open interfaces to other systems and domains.

The relations of ThinkHome to GREENERBUILDINGS are summarized in Figure 4.3.5.

4.4 SEEMPubS

4.4.1 Abstract

SEEMPubS [owpj] (Smart Energy Efficient Middleware for Public Spaces) specifically addresses reduction in energy usage and CO2 footprint in existing Public buildings and Spaces without significant construction works, by an intelligent ICT-based service monitoring and managing the energy consumption.

The SEEMPubS research is funded by the European Commission, within the Seventh Framework Programme. It started in September 2010 and has a time frame of 36 months.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency						
Scalability			User Agent, Context Inference Agent, Auxiliary Data Agent	Multi–Agent System	Agent Framework	
Privacy						
Costs						
User comfort						
Adaptability			User Agent, Context Inference Agent, Auxiliary Data Agent	Multi–Agent System	Agent Framework	
System reliability						
Data security						
Dynamicity			User Agent, Context Inference Agent, Auxiliary Data Agent	Multi–Agent System	Agent Framework	
Standard Compliance						

Table 4.3: ThinkHome relations

4.4.2 Goals

SEEMPubS's goal is the adoption of a semantic service-oriented architectural solution, namely HYDRA [owpc], as a support for a novel, integrated ICT-based management and intelligent control system able to govern different energy-efficient sub-systems deployed in spaces of public use. In particular, SEEMPubS aims at raising users' awareness of energy consumption in public spaces and at involving the users themselves in the global process finalized to achieve the main objective, i.e. energy efficiency.

4.4.3 Approach

SEEMPubS aims at raising users' awareness of energy consumption in public spaces and at involving the users themselves in the global process finalized to achieve the main objective, i.e. energy efficiency. In order to get such results, a multi-disciplinary approach is needed, including energy consumption monitoring, building and neighborhood management systems, energy efficiency, modeling and simulation, context awareness, user awareness and interaction.

1. SEEMPubS not only proposes solution provides the capabilities to enable an effective integration at building level (among different sub-systems) but also to support the integration of the resulting smart energy efficient building and surrounding environment into a smart grid scenario.

2. SEEMPubS addresses the heterogeneity-related issues by utilizing Hydra middleware as underlying technology.

3. SEEMPubS will analyze the issues and will define novel solutions to manage energy efficiency in networks of sensors and actuators.

4. SEEMPubS will design a novel ICT-based management and intelligent control system leveraging the cooperation among components of the same sub-system and among different sub-systems.

4.4.4 Outcomes

At the time of writing the project is still ongoing so a final outcome on the complete benefits it has brought are not available.

However, it is worth referring to HYDRA outcomes because SEEMPubS takes advantage of the HYDRA project.

4.4.5 Relation to GREENERBUILDINGS

The main focus of SEEMPubS is to develop a middleware for energy savings in buildings. The middleware will be developed based on existed HYDRA platform thus GREENERBUILDINGS can take advantage of HYDRA platform when designing the composition layer. On the other hand, since SEEMPubS's objectives are quite similar to those of GREENERBUILDINGS, the procedure and the ways of approaching the solution may have some commonalities.

- **Sensors & wireless technology:** In the area of energy efficiency in networks of sensors and actuators, SEEMPubS will investigate both lower level (considering specific sensor technologies) and higher level (leveraging on the considered Hydra middleware)

- **Middleware & compositional approaches:** In the area of composition layer, SEEMPubS will design a novel ICT-based management and intelligent control system leveraging the cooperation among components of the same sub-system and among different sub-systems.

- **System architecture:** In the area of heterogeneity-related issues, HYDRA middleware is expected to support interoperability and integration.

- **Smart grid:** In the area of Smart metering and smart grid interconnection, SEEMPubS proposes *Advanced Metering Infrastructure* solution enabling the bi-directional communication with smart meters.

The relations of SEEMPubS to GREENERBUILDINGS are summarized in Table 4.4.5.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency						Advanced Metering Infrastructure
Scalability				HYDRA middleware	HYDRA platform	Advanced Metering Infrastructure
Privacy						
Costs						
User comfort						
Adaptability				HYDRA middleware	HYDRA platform	Advanced Metering Infrastructure
System reliability						
Data security						
Dynamicity					HYDRA platform	Advanced Metering Infrastructure
Standard Compliance						

Table 4.4: SEEMPubS relations

4.5 Development of a Testbed for Wireless Sensor Networks in Building Automation Projects

4.5.1 Abstract

Wireless sensors can lead to energy savings in buildings by providing more detailed information on building conditions that can then be used to identify alternative control schemes or to detect faulty operation that is wasting energy.

Potential users of this technology, however, have concerns about the reliability of data transmission in buildings as well as the power requirements of battery-powered wireless sensors. The purpose of this project [oTfWSNUiBPwp] is to provide experimental data on these key aspects of wireless sensor performance in buildings and to develop tests that potential users of wireless sensors can conduct to help them assess the sensors' performance in their particular applications.

The project is led by Engineering Laboratory Unit – The National Institute of Standards and Technology (NIST) – The U.S. Commerce Department.

4.5.2 Goals

The goals of the project are to help users of wireless sensor technology gauge the effectiveness of systems in particular buildings as well as to provide developers of wireless sensor hardware and software a target to which systems should be designed.

4.5.3 Approach

The project proposes to develop a testbed comprised of several modules that will be used to measure the performance of a wireless sensor network in building–related applications.

Each module of the testbed will focus on a different performance metric that is of importance to engineers who make use of the technology.

The technical approach that will be pursued to overcome the obstacles in adopting wireless technology in buildings is demonstrated by the current development of a test method to assess the quality of a wireless link in various building scenarios.

After carrying out exploratory research to scope the particular challenges in buildings, a short series of tests will be developed that can be used to predict the communication link quality for a particular building's construction. The data that result from these measurements can, for example, be used to predict allowable spacing between adjacent wireless communication points to ensure high transmission success rate and optimal network topology.

4.5.4 Outcomes

At the time of writing the project is still ongoing so a final outcome on the complete benefits are not available.

Nonetheless, during 2008, the project interviewed over 30 people from the building automation sector, the research community, building operations sector, and wireless hardware industry to understand the obstacles in adopting wireless technology in buildings. These discussions indicated that users are concerned about a variety of issues, notably interference, battery life, ease of use, robustness, reliability, and security.

In 2009, the first issue evaluated was the effect of different building construction on transmission of wireless signals. In this work, a series of scoping experiments were carried out which led to a method to predict the percentage of successful signal transmissions as a function of location within a building.

In addition, the project developed needs assessment that will serve as the basis for an R&D plan that will provide measurement techniques that gauge wireless sensor network performance.

Some publications [HJ08, JH10] are listed in Bibliography section.

4.5.5 Relation to GreenerBuildings

The area related to GreenerBuildings is mainly the assessment of the performance and reliability of Wireless Sensor Networks.

- **Sensors & wireless technology:** In GreenerBuildings, Wireless Sensor Network plays a key role at pervasive layer, gathering user activity, building utilization and building context. The measurement science to describe how wireless systems will work is very important. GreenerBuildings can take advantage of this project to assess the performance and reliability of wireless sensor networks.

4.6 BeyWatch (Building EnergY WATCHer)

4.6.1 Abstract

BeyWatch [owpa] project aims at helping reducing energy consumption at household level by developing and evaluating innovative user-centric solutions to raise energy awareness and usage flexibility.

The project is led by Spanish telecommunication company Telefonica and it started in December 2008 and has a time frame of 30 months.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency						
Scalability						
Privacy						
Costs						
User comfort						
Adaptability		WSNs Testbed				
System reliability						
Data security						
Dynamicity						
Standard Compliance						

Table 4.5: Development of a Testbed for WSNs in Building Automation Projects relations

4.6.2 Goals

The main goal of BeyWatch is to save energy by making users aware of their energy consumption, and thus expenses, and enabling them to intelligently control home energy usage (in particular hot water and electricity). As a second objective, BeyWatch aims at efficiently distributing home saved or unused electricity energy at neighboring level, allowing for electricity load balance and flexible usage based on the moment of consumption. With the improvement of energy efficiency at home and neighborhood scale, BeyWatch can have a positive impact to reduce the carbon dioxide emissions and the energy bills.

4.6.3 Approach

BeyWatch solution provides interactive energy monitoring for white goods, intelligent control of devices and their power demand in order to achieve balancing at home, block and neighborhood level. This is done by working on two main elements:

- First by minimizing energy consumption of white goods and electronic devices;
- Second by achieving balance in the energy distribution system at local level.

These two aspects provide energy savings and while reducing cost for energy distribution service operations as well.

From a technological and communication perspective BeyWatch wanted to use a low power, low data rate, long life battery and secure networking that produced a short list of possible technologies to be used: ZigBee, 6LoWPAN and PLC.

4.6.4 Outcomes

At the time of writing the project is still ongoing so a final outcome on the complete benefits it has brought are not available.

Nonetheless an architecture to monitor electrical appliances and control their behavior has been created based on an agent supervision. The efficiency is not only achieved at local level, but with an interaction between micro and macro management the benefits are extended to a bigger community (e.g., neighborhood). The BeyWatch Residential Gateway is an embedded system acts as a service gateway for control and automation of building devices.

The developed platform performs communications, monitoring and control functionalities over the different devices inside the household such as white appliances (e.g., washing machine, dishwasher and refrigerator), energy watchers (e.g., energy-aware smart plugs) and small scale generating systems (e.g., photovoltaic and solar thermal panels).

From a middleware perspective BeyWatch uses TID Device and Event Management Framework based on the experience of one of the partners (Telefonica): this is a three-layered framework with network, device and application layer; all the services provided by the middleware are provided as OSGi service bundles to guarantee modularity and extensibility.

The chosen technology for the communication between home devices is IEEE 802.15.4 as standard for the lower layers of the architecture and use ZigBee technology on top.

4.6.5 Relation to GREENERBUILDINGS

BeyWatch project is relevant to various extents to the GREENERBUILDINGS project.

A remarkable element is the use of BeyWatch Agent whose most important functionalities for GREENERBUILDINGS are:

- **Sensors & wireless technology:** In the area of Sensor and Wireless Technology, Beywatch analyses and implements IEEE 802.15.4/ZigBee protocols.
- **Context & activity recognition:** The context in Beywatch is retrieved based on the user input provided to BeyWatch Agent, by the actual monitoring of appliances and

sensors and also by historical data and statistics. A remarkable element is the use of BeyWatch Agent whose most important functionalities for GREENERBUILDINGS are:

  - **Monitor, control and report current and past data:** this data contains information about consumption for the various appliances (electrical energy consumed, current and past instant power used) and also provides data for the house as a whole. It also includes information on the power generated through photovoltaic cells.
  - **Interact with user to obtain preferences and requirements:** User input allows humans to specify preferences how to control certain appliances.
  - **Collect and inspect historical statistics:** These are another source of information that affects the optimization decisions the agent makes. These are historical statistics that capture recurring patterns of behavior in the energy demands generated by the inhabitants of the house.
  - **Optimally control appliances:** Controlling appliances in an optimal way is the main role of the BeyWatch Agent. The agent requires some information in order to make the right choices and actuate to impose the selected ones.

- **System architecture:** Another interesting aspect of BeyWatch for GREENERBUILDINGS project resides in the way the coordination at very small–scale and at medium–scale is obtained through two levels of hierarchy:

  - **Micro-management level:** It acts at local (i.e., household) level based on several variables such as outdoor temperature, power consumption demand, power network conditions and the users' preferences. The various local devices in home or building are under local interactive monitoring and intelligent control in order to obtain a reduction of loads on the local Grid and reaching peak smoothing at small–scale. The micro–management level also deals with information about the energy flow coming from small–scale generators panels in the premise.
  - **Medium–management level:** The local control elements is included in a hierarchical system that covers larger geographical region (e.g. blocks or neighborhood) to provide statistical data and enable medium–level control and coordination of small-scale energy resources.

- **Smart grid:** In the area in Smart Grid, BeyWatch designs and implements a "Supervisor" system. This is an open and distributed system/platform for the management and control of energy consumption and power demand at a local/square or urban geographical level.

The relations of BeyWatch to GREENERBUILDINGS are summarized in Table 4.6.5.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency	Home Area Network					
Scalability						
Privacy						
Costs						
User comfort	Micro management		User input - User preference profiling			
Adaptability	Micro management		Historical Data			
System reliability						
Data security						
Dynamicity						Micro management – Supervisor system
Standard Compliance		802.15.4 - Zigbee				

Table 4.6: BeyWatch relations

4.7 Smart Houses Interacting with Smart Grids to achieve next-generation energy efficiency and sustainability (SmartHouse/SmartGrid)

4.7.1 Abstract

Motivated by the European initiative 202020, SmartHouse/SmartGrid [owpl] aims to validate and test how Information and Communication Technology (ICT) can enable collaboration and aggregation of Smart Houses in order to provide an essential step to achieve the European energy efficiency challenges.

In the project, various partners are present from three countries: Germany (SAP Research, IWES – Fraunhofer Institute for Wind Energy and Energy System Technology, MVV Energie), the Netherlands (ECN – Energy Research Centre of the Netherlands) and Greece (ICCS – Institute of Communication and Computer Systems of University of Athens, PPC – Public Power Corporation). The project started in 2008 and the completion is expected in mid 2011.

4.7.2 Goals

There are three high-level goals SmartHouse/SmartGrid project aims at achieving: first of all obtaining an improvement in energy efficiency; advancing in the penetration of renewable energies; and realizing a diversification and decentralization of European energy mix. Of course these high level goals are then tackled from an ICT perspective in creating and adapting actual technologies to help achieving the objectives stated above.

In order to improve energy efficiency ICT plays an important role in transforming electricity sector, enabling it to manage more decentralized and renewable generation systems efficiently. Following these goals SmartHouse/SmartGrid builds its foundations on:

- Open industry standards from both ICT and energy sectors;
- Communication and computing capabilities already abundantly present in home and working environments.

Therefore the project aims at obtaining a mass application of the technology proposed aggregating smart houses, managed by intelligent networked ICT, to guarantee flexibility even at higher scale.

4.7.3 Approach

From a software architecture perspective it is interesting how two different solutions are adopted in the various situations in which the communication takes place. In fact, inside the premise the appliances (that generally can be heterogeneous) have two fundamental ways to interact either directly, in a peer–to–peer fashion, or through an "enterprise assisted" mechanism for those low level devices that need specific ways to interact with others. The communication with devices or data sources/sinks outside the premise is realized using web-service technology.

In order to enable the inter-relationship of the different components of the Smart Grid a common ontology is used and it is based on the Common Information Model (CIM) that is a result of standardization process of IEC–61970 and IEC–61968. A final aspect to remark is the use of PowerMatcher concept to enable the interaction between energy trading and related markets.

From a communication point of view appliances and sensor used to communicate do not have to belong to a special technology, the project allows the integration of various different solutions such as ZigBee, Zwave and KNX.

4.7.4 Outcomes

At the time of writing, the project is still ongoing so a final outcome on the benefits it has brought are not available.

However the SmartHouse/SmartGrid project has developed field tests in three different countries, where proofs of concept of specific aspects of the new technologies introduced are shown:

- The management of large-scale communication, negotiation and information exchange between many thousands of smart energy devices at the same time; this aspects are managed in the Netherlands.
- The interaction in a smart way with the end users and optimal home energy management as a response are tested Germany.
- Control of smart energy devices in a decentralized and bottom-up way are managed in Greece. This last topic aims at obtaining optimum energy efficiency at the aggregate level, together with high security of supply levels for the end user.

The consortium has realized an Enterprise Integration Architecture to enable enterprise high-level applications to interact with each other and consume data from a wide range of networked devices using high-level abstract interfaces based on web services standards. Agent technology is also used for Multi-Agent Systems that are required to control a single micro-Grid and the interaction between many; the technology used for these agents is JADE.

4.7.5 Relation to GREENERBUILDINGS

The project has various aspects relevant to GREENERBUILDINGS even if the focus of SmartHouse/SmartGrid is more oriented on the interaction between devices in order to have a Grid that is always in balance.

- **Building automation & operational services:** From a building automation perspective SmartHouse/SmartGrid focuses on achieving automation making the appliances interacting with the balancing/unbalancing situation of the Grid with the ultimate goal of improving efficiency in the overall network. The idea is to control the devices in order to increase/decrease their power consumption based on the needs of the user and on the congestion of the Grid. Relevant aspects for GREENERBUILDINGS are also the usage of data gathering to perform statistical analysis with which extract pattern to better understand the use of appliances and therefore energy consumed by end users.

- **Sensors & wireless technology:** In the area of Sensors and Wireless technology, the aspect that should be considered and addressed properly in GREENERBUILDINGS is the integration of various technologies and standards, such as ZigBee, Zwave, KNX, etc. SmartHouse/SmartGrid has tackled this issue.

- **Context & activity recognition:** The performed statistical elements are used together with user inputs in order to provide the highest energy efficiency without losing the comfort and choices of the user.

- **Middleware & compositional approaches:** Two different solutions are adopted in the various situations in which the communication takes place. Inside the premise the appliances, there are two fundamental ways to interact either directly, in a peer–to–peer fashion, or through an "enterprise assisted" mechanism for those low level devices that need specific ways to interact with others.

- **System architecture:** From a system architecture perspective, the coordination of various systems in a distributed environment are tacked in this project, the same challenge, although not for Grid balancing purposes, are present in GREENERBUILDINGS.

- **Smart grid:** As the title suggests, the project is more related to the relationship between a Smart House and the Smart Grid, and how to achieve efficiency in the overall electrical system and not only at single building level. In order to enable the inter-relationship of the different components of the Smart Grid a common ontology is used. This ontology is based on the Common Information Model (CIM) that is a result of standardization process of IEC–61970 and IEC–61968.

The relations of SmartHouse/SmartGrid to GREENERBUILDINGS are summarized in Table 4.7.5.

4.8 Aura

4.8.1 Abstract

The Aura project [aura] focusses on how applications can proactively adapt to the environment in which they operate, thus providing users with more intelligent behavior of applications and allowing users to focus on higher level tasks. Environmental information is required for this, for instance locations of users, availability of printers and available bandwidth.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency						Dynamic load and supply
Scalability				Outside: web services. Inside: P2P, enterprise assisted interaction		
Privacy						
Costs						
User comfort			User input, Statistical analysis			
Adaptability			Statistical analysis		Enterprise Integration Architecture	
System reliability						
Data security		ZigBee				
Dynamicity	Statistical analysis Grid balancing based					
Standard Compliance		Integration of various technologies (ZigBee, Zwave, KNX)				

Table 4.7: SmartHouse/SmartGrid relations

4.8.2 Goals

The main goal of project Aura is to focus on user attention and to create a system that does not distract the user. Handheld devices like mobile phones tend to take all of the users attention even to get simple tasks done. Aura will realize this goal by creating a framework that is able to: "provide each user with an invisible halo of computing and information services that persist regardless of location." Project Aura will design, implement, deploy, and evaluate a large-scale system demonstrating the concept of a personal information aura that spans wearable, handheld, desktop and infrastructure computers.

Aura project will contribute in the fields of energy-aware adaptation, pervasive systems, user interaction, privacy and services among others.

4.8.3 Approach

Aura is a large scale research project where several research technologies are being explored. Contributions are made in various fields. Energy-aware adaption is being addressed in the following research topics:

- Dynamic change of application fidelity for reduced energy use.
- Tools for mapping energy use to software structure.
- Graceful integration with hardware-level power management.

Additional research topics/technologies that are addressed are:

- Proactive interactions with users
- Network weather service
- Resource opportunism

4.8.4 Outcomes

The outcomes are mainly in publications on a number of research topics. Notable papers are published on pervasive computing [Sat01, JS03], energy-aware adaptation and privacy. Furthermore a framework is developed where services follow users moving in a space. For instance someone is watching a video clip in the living room decides to move to the living room. The video clip continues to play on the laptop on the dinner table. In another corner it is decided that the best way to provide this service is to play the music over a radio [SG01, aurb].

4.8.5 Relation to GREENERBUILDINGS

The relation to GREENERBUILDINGS is most clear in the focus on context awareness and pervasive computing as the Aura framework constantly has to be aware of its users. However, Aura puts much emphasis on security.

Fields of interest to GREENERBUILDINGS that Aura covers are:

- **Context & activity recognition:** Aura has to be constantly aware of what users are doing in order to provide them with the best services. The FollowMe feature of Aura is able to provide a user with music anywhere in the home. It uses RFID tag readers around the house to locate the user and provides services based on user location.

- **Middleware & compositional approaches:** Aura is able to do various simple tasks for the user, checking whether services like printing are available, sending messages to other people's Auras, sending e-mails and so on.
- **System architecture:** A service checking facility is present in each room of the house. The user's Aura is checks where these services are, and activates them for the user as necessary. When a user is located in a new location, aura automatically finds the best service in the new location.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency						
Scalability						
Privacy						
Costs						
User comfort		RFID	FollowMe		Aura	
Adaptability						
System reliability						
Data security						
Dynamicity						
Standard Compliance						

Table 4.8: Aura relations

4.9 Amigo

4.9.1 Abstract

Amigo's shortest description is "ambient intelligence for the networked home environment." Amigo [ami] provides an interoperable middleware which enables ambient intelligence within the networked home environment. This is done by addressing the seamless integration of networked devices and related application services within the home system. The Amigo interoperable middleware architecture is specifically designed to realize an open networked home system that dynamically integrates heterogeneous devices as they join the network.

4.9.2 Goals

The project develops applications in different domains to show the potential for end-users and the benefits of the service oriented-middleware architecture for application developers. The targeted domains are:

- Home Care and Safety,
- Home Information and Entertainment, and
- the Extended Home Environment in which multiple homes are connected.

A major goal is to provide end-users with services that enable them to share activities and experiences in an easy and personalized way. They can socialize and visit from their personal environment, with friends and relatives at remote locations. One can use a personal device, for example a mobile, in somebody else's home network for using the services in their own home. Such a device enables users to remotely access services which are operating in their own home. This computing device travels with the user and can bind a visited domain to a home domain.

4.9.3 Approach

The Amigo Open Source Software follows the paradigm of Service Orientation, which allows developing software as services that are delivered and consumed on demand. The benefit of this approach lies in the loose coupling of the software components that make up an application. Discovery mechanisms can be used for finding and selecting the functionality that a client is looking for. Many protocols already exist in the area of Service Orientation. The Amigo project supports a number of these important protocols for discovery and communication in an interoperable way. This makes it possible for programmers to select the protocol of their choice while they can still access the functionality of services that are using different methods. In this way, various existing standards are integrated.

4.9.4 Outcomes

The final result of the Amigo project is a framework that intelligently monitors users, and allows communication between residents from different locations. It is an ambient intelligent architecture that focusses on home care and safety, home information and entertainment and communication.

Being a research project, a number of contribution have also been made as publications, most notably in the field of dynamic service composition such as in [VRV05] and user interfaces for multi-user awareness systems [ER07].

4.9.5 Relation to GREENERBUILDINGS

The most clear component that Amigo has in common with GREENERBUILDINGS is ambient intelligence. Amigo relies heavily on context and activity information and uses it to notify users of their environment.

Amigo has made contributions in the following fields.

- **Context & activity recognition:** Amigo provides services to users based on user activity. For example, Amigo plays music on waking up with volumes adapted to the bedroom environment. Another example shown in the Amigo video is that the user receives a message when forgetting to take her ID badge when leaving the house. It is not explained how they want to reach this level of activity and context recognition.
- **Middleware & compositional approaches:** Amigo aims to make integration of standards easy, allowing developers to use the standards and techniques they are most comfortable with. This is done by integrating a number of popular standards.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency						
Scalability						
Privacy						
Costs						
User comfort			Addressed			
Adaptability			Addressed	Open Source		
System reliability						
Data security						
Dynamicity						
Standard Compliance				Amigo		

Table 4.9: Amigo relations

4.10 House_n

4.10.1 Abstract

House_n [hou] is a multi-disciplinary project lead by researchers at the MIT Department of Architecture. It focusses on designing and building real living environments that are used to study technology and design strategies. Participants include the MIT Media Lab and other departments at MIT, Intel Research, the Boston Medical Center, Stanford Medical, University of North Carolina School of Public Health, Bensonwood Homes, and CIMIT.

4.10.2 Goals

House_n research is focused on how the design of the home and its related technologies, products, and services should evolve to better meet the opportunities and challenges of the future. The mission of House_n is to conduct research by designing and building real living environments - “living labs” - that are used to study technology and design strategies in context, the most important living lab being “PlaceLab”. The PlaceLab is being used to investigate a variety of research questions:

- How can technology be effective in the home context for long time periods?
- How can technology be used to simplify the control of homes of the present and future, save resources, and improve health?
- What new innovations for the home would most fundamentally alter the way we live our everyday lives?

In particular, House_n is devoted to human behavior and how people react to large amount of technology in their daily environment.

4.10.3 Approach

Massachusetts Institute of Technology researchers are investigating methods for merging new technologies with person-centered design. They are generating new ideas, technologies, and methodologies that support the creation of innovative products and services that satisfy the emerging and future needs of people as they live in their homes. This broad research approach is leading to innovative product ideas that are unlikely to be uncovered in more narrowly-focused industries or research endeavors. To facilitate these studies, a unique “living laboratory” residential home research facility called the PlaceLab has been constructed near MIT.

4.10.4 Outcomes

The House_n project has supported several living labs, the most important of which is the PlaceLab. Hundreds of sensing components are installed in nearly every part of the home, which is a one-bedroom condominium. These sensors are being used to develop innovative user interface applications that help people to:

- easily control their environment,
- save resources,
- remain mentally and physically active, and
- stay healthy.

The sensors are also being used to monitor activity in the environment so that researchers can carefully study how people react to new devices, systems, and architectural design strategies in the complex context of the home.

MITes are another outcome of the House_n project. They are sensors that are easy to use and install, developed to conduct research in everyday places of living, work environments, and public spaces. They are affordable, easy to install and remove, unobtrusive and informative.

A number of publications in the fields of ubiquitous computing, activity recognition, and healthcare have been made.

4.10.5 Relation to GREENERBUILDINGS

The most obvious relation to GREENERBUILDINGS can be seen in the areas of ubiquitous computing and activity recognition. House_n project has developed and used different types of sensors that monitor user activity and energy usage, that are possibly relevant to GREENERBUILDINGS.

Areas of interest that relate to GREENERBUILDINGS include:

- **Sensors & wireless technology:** The PlaceLab uses hundreds of sensors to monitor user activity. Sensors are installed on the objects that people touch and use: cabinet doors, drawers, controls, furniture, passage doors, windows, containers, etc. Moreover, audio and video are captured. Environmental conditions are sensed too.

  MITes are sensors that monitor environmental conditions and are designed to be easy to install and use.
- **Context & activity recognition:** The rich sensing infrastructure of the PlaceLab will be used to develop techniques to recognize patterns of sleep, eating, socializing, recreation, etc. Moreover, the PlaceLab is designed for physiological medical monitoring.

- **System architecture:** The PlaceLab is formed by 15 prefabricated cabinetry interior components. Each contains a micro controller and network of 25 to 30 sensors. Information from these components is combined and processed centrally.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency		MITes				
Scalability						
Privacy						
Costs						
User comfort		MITes/ PlaceLab		PlaceLab		
Adaptability						
System reliability						
Data security						
Dynamicity						
Standard Compliance						

Table 4.10: House_n relations

4.11 Bode

4.11.1 Abstract

Bode [bod] deals with occupancy measurement, modeling and prediction for building energy savings. A system for occupancy monitoring is essential to solving the fundamental building energy management problem. Perhaps just as important as an occupancy estimation system are occupancy prediction models. This needs to be addressed since conditioning a room is not instantaneous and requires time for adjustments.

4.11.2 Goals

Bode project develops a system that tracks user movement in building spaces using a camera network solution called SCOPES (a distributed Smart Cameras Object Position Estimation System). To use this information, Bode aims to develop a framework that estimates and predicts user occupation of building spaces. This information is then to be used to save energy in various areas, most notably HVAC and lighting. Traditionally, for instance, a conference room could be conditioned assuming an occupancy of 30 people when only 20 people actually use the room. Bode aims to develop a framework that conditions the conference room for 20 people instead of 30. Also, it is possible to avoid conditioning the room when empty.

4.11.3 Approach

SCOPES balances the trade-offs associated with camera sensor networks. Each node in the system is comprised of a Cyclops camera that performs local detection and processing of the visual information and a Tmote sensor node, which provides power and multi-hop communication capability. By aggregating meta-information generated by each node, SCOPES is able to minimize the total data transmitted in the network and still be able to generate an accurate density estimation map of the coverage area.

Models of occupancy can be created by gathering data over a long period of time using a system such as SCOPES. Bode developed a Multivariate Gaussian model and an agent based model using several days of ground truth occupancy data. The agent based model simulates occupancy by modeling the behavior of the individual.

Using occupancy models to examine user mobility patterns in buildings, SCOPES can predict room usage which enables controlling the HVAC systems in an adaptive manner.

4.11.4 Outcomes

A camera network was developed that is able to monitor room occupancy. By controlling HVAC using a multivariate Gaussian model and an agent based model occupancy predictions, simulations indicate a 14% reduction in HVAC energy usage by having an optimal control strategy based on occupancy estimates and usage patterns.

Being a research project, a number of publications have been made. "Energy Efficient Building Environment Control Strategies Using Real-time Occupancy Measurements" gives a good overview of the framework that is used in the Bode project [ELK$^+$09]. Interesting results concerning the wireless communication are found in [KCPnC09].

4.11.5 Relation to GREENERBUILDINGS

Due to the strong emphasis on occupancy monitoring and prediction, the results of this project are very interesting to GREENERBUILDINGS. Furthermore, these results are used to control energy usage.

The contributions of Bode relevant to GREENERBUILDINGS are mainly in the following areas:

- **Sensors & wireless technology:** Camera solutions are used to monitor movement and track users. Tmote sensor nodes are used for multi-hop wireless communication. This is not directly relevant to GREENERBUILDINGS because the whole setup relies heavily on the use of cameras to track people.

- **Context & activity recognition:** Occupancy prediction models are generated from several days of ground truth occupancy data. Agent based models simulate occupancy by modeling the behavior of the individual. Occupancy modeling and prediction is very relevant to GREENERBUILDINGS they allow for room conditioning on large timescales.

- **Middleware & compositional approaches:** The Tmote sensor nodes allow wireless multi-hop communication. Processing of visual information is done on the node. Wireless communication might be relevant to GREENERBUILDINGS.

- **System architecture:** SCOPES is the complete system used in the Bode project. It is responsible for wireless communication, data processing and occupation modeling and prediction. Since this system relies heavily the use of cameras, relevance to GREENERBUILDINGS is small.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency		Tmote/ Cyclops	Occupancy modeling/ prediction	SCOPES	SCOPES	
Scalability						
Privacy						
Costs						
User comfort			Occupancy modeling/ prediction			
Adaptability						
System reliability						
Data security						
Dynamicity						
Standard Compliance						

Table 4.11: Bode relations

4.12 iSpace

4.12.1 Abstract

iSpace [isp] is a student study bedroom that was built by re-fitting a room on the campus of the University of Essex. iSpaces furnishings are fitted with intelligent gadgets that can detect and learn the occupants behavior with the aim of providing services that could improve the quality of their lives by generating an environment that suits their needs.

4.12.2 Goals

iSpace was built as a research project to investigate the feasibility of the intelligent environment. Several outcomes were kept in mind when designing the iSpace. First of all the user behavior should be modeled. Secondly, this user behavior and user preferences should be applied automatically achieving optimal user comfort and energy efficiency.

4.12.3 Approach

iSpaces furnishings are fitted with intelligent gadgets that can detect and learn the occupants behavior. These intelligent gadgets communicate with each other allowing groups of agents to coordinate their actions, and allowing remote access to their services via networks (e.g. Internet, GSM etc). In addition, the iSpace is fitted with myriad of sensors and effectors to enable the intelligent agents to monitor and make changes to the room's environmental conditions. The iSpace network is configured in such a way that the status of the effectors can be monitored and adjusted by both local or remote users, or the agents embedded within the iSpace environment. In other words, the agent can intelligently remember the users habits under particular environmental conditions and then make changes to the environment according to those habits.

4.12.4 Outcomes

iDorm is an installation of gadgets, sensors and effectors in a student bedroom. A second installation has been made in iDorm2. This is a two bedroom apartment with an installation of sensors and actuators heavily influenced by iDorm. A thorough description of the implementation can be found in the book chapter [CCH+05].

4.12.5 Relation to GREENERBUILDINGS

The focus on modeling user preferences and automatically creating a comfortable environment for users are very interesting to GREENERBUILDINGS.

The project has focusses on the following topics.

- **Building automation & operational services:** Various services are available that allow the conditioning of the space.
- **Sensors & wireless technology:** A myriad of gadgets allows to detect the occupant's behavior.
- **Context & activity recognition:** This is the strongest focus of the project. The gadgets that are installed in the iSpace are capable of learning user behavior. This is done by remembering preferences in typical scenarios. This is interesting as conditioning spaces to user preferences is a goal GREENERBUILDINGS too.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency	'Intelligent gadgets'	'Intelligent gadgets'	Addressed			
Scalability						
Privacy						
Costs						
User comfort	'Intelligent gadgets'	'Intelligent gadgets'	Addressed			
Adaptability						
System reliability						
Data security						
Dynamicity						
Standard Compliance						

Table 4.12: iSpace relations

4.13 Smart-A

4.13.1 Abstract

The main objective of the Smart-A project [sma] is to identify and evaluate the potential synergies that arise from coordinating energy demand of domestic appliances with local sustainable energy generation but also with the requirements of regional load management in electricity networks.

4.13.2 Goals

The Smart-A project explores the possibility for smart appliances to adapt their operation to variations in the local and regional energy supply. In other words, how can the appliances operate with more flexibility but without compromising the quality of the service delivered by the appliances.

In order to assess the potential for synergies between appliances and energy supply systems, the Smart-A project team will analyze the communication interfaces that connect the loads and generators/supply sources. In particular, the additional cost and energy demand of these smart elements will be assessed.

For each appliance, it will be necessary to:

- Model the operation and energy demand of the appliance,
- Analyze the options for load shifting, and
- Assess the impact on appliance design and service provided.

4.13.3 Approach

Smart-A project investigates the feasibility of smart appliances by developing guidelines for relevant stakeholder groups, based on a certain set of scenarios. These guidelines include recommendations on

- how appliances should be designed,
- how appliances can be integrated in a smart energy network,
- the design of energy supply systems, and
- how to balance power consumption.

4.13.4 Outcomes

The outcomes of the project are provided in the form of reports on demand response options for

- domestic appliances,
- consumer acceptance,
- impact of smart appliances on local energy systems,
- potential overall costs and benefits of smart appliances,
- implementation models, and
- implementation strategies.

All these results are presented in the final project deliverable [Tim09].

4.13.5 Relation to GREENERBUILDINGS

Considering the work done in the Smart-A project, there is not a strong relation to GREENERBUILDINGS. However, some final results are of importance. Especially the guidelines on how to prepare smart appliances for future uses of the energy nets.

Areas of focus of the Smart-A project include the following.

- **Building automation & operational services:** Smart-A project is focussing on smart appliances that can react to energy supply variations.
- **System architecture:** Guidelines on how a system should deal with different appliances to take advantage of differing energy demands are given. These are not very relevant to GREENERBUILDINGS.
- **Smart grid:** Smart-A explores how appliances can react to energy supply variations, and how they should be designed to connect to the energy net.

The connection to the smart grid is something that GREENERBUILDINGS should take into account because it will be very relevant in the future.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency	Smart appliances				Energy supply systems	Smart appliances
Scalability						
Privacy						
Costs	Smart appliances					
User comfort						
Adaptability						Smart appliances
System reliability						
Data security						
Dynamicity						
Standard Compliance						

Table 4.13: Smart-A project relations

4.14 eDIANA

4.14.1 Abstract

eDIANA (Embedded Systems for Energy Efficient Buildings) [edi] is a research project co-founded by ARTEMIS-JU and by National Authorities of each partner. eDIANA addresses the need of achieving energy efficiency in buildings (both private and public) through innovative solutions based on embedded systems. Embedded systems are today a reality; however, their applicability is limited by the lack of interoperability. To this hand, eDIANA focuses on the design, development, demonstration and validation of a new platform interconnecting heterogeneous devices in a unique complex network.
eDIANA is a 36 months project and it started on February 2009.

4.14.2 Goals

The goal of the project is to develop a technology (eDIANA platform) to improve energy efficiency and optimize buildings energy consumption by 25%, providing real-time measurement, integration and control. Moreover, user comfort will be considered as fundamental and it will be improved, making the user aware, and enabling user-controlled policies for household devices (lighting, domestic electronics, etc.).
The expected output of the project is the provisioning of a reference model-based architecture, implemented through an open middleware including specifications, design methods, tools, standards, and procedures for platform validation and verification. eDIANA Platform will enable the interoperability of heterogeneous devices at the Cell and MacroCell levels, and it will provide the hook to connect the building as a node in the producer/consumer electrical grid.

4.14.3 Approach

eDIANA will provide a Reference Architecture for a network of composable, interoperable and layered embedded systems that will be instantiated to several physical architectures. The modularity of the approach is given by the definition of Cell and MacroCell. A cell is a living or working unit, while a MacroCell is an aggregation of several cells and is generally represented by a residential or non residential building. The interoperability of the platform is achieved by the definition of intelligent interfaces to connect devices to the system and by the adoption of standards to implement all the communications. The eDIANA Platform implementation will cope with a variable set of location and building specific constraints, related with parameters such as climate, Cell/MacroCell configuration (one to many, one to one etc), energy regulations etc.

4.14.4 Outcomes

The eDIANA project is at the end of the second year and the main outcomes obtained until now can be basically divided in prototypes and scientific publications. Concerning prototypes, basic building blocks of the eDIANA architecture (e.g. cell level concentrator, intelligent Embedded interface, Macro-cell level concentrator etc...) are going to be released as not integrated components. In particular, in [CCV$^+$10] a demonstration of the communication between sensors and the Cell Device Concentrator (CDC) is presented. The wireless sensor network is composed of IEEE $802.15.4$/ZigBee devices transmitting data to the ZigBee coordinator, located inside the CDC. Multi-hop ZigBee networks have been formed and latency measurements conducted in different number of hops. The realized prototype provides a basis for the development of the eDIANA platform.
Concerning scientific publications, the main results can be found in [S.11], [CAR10].
In [S.11] the author provides an analysis about the best way to provide feedback on electricity consumption. The results show that the following features of feedback on electricity consumption are most valued by consumers: presentations of costs (over a period of time), appliance-specific breakdown, i.e. information on what proportion is consumed by each appliance, and historical comparison, i.e. comparison with their own prior consumption.
In [CAR10] it is shown a performance evaluation of the network used to sense information with the aim to show the applicability of the IEEE 802.15.4 standard to the eDIANA application scenario and provide some guidelines for designing the network. A building composed of apartments has been considered as case study and a number of IEEE 802.15.4 standard-compliant sensors are distributed in the buildings. Performance, in terms of packet error rate, average delays, and energy consumption, is evaluated, and the impact of the interferences is shown. Moreover, different network topologies are studied and compared.

4.14.5 Relation to GREENERBUILDINGS

In the following we summarize the main contributions of eDIANA and the relations with GREENERBUILDINGS:

- **Sensors & wireless technology:** the eDIANA platform is built following the ZigBee specification which defines specific profiles for energy efficiency, building automation, etc... Therefore, the results following from the eDIANA platform evaluation can be used as input to decide whether or not ZigBee can be used also in GREENERBUILDINGS.

- **Context & activity recognition:** In eDIANA, users express their preferences and drive the platform toward the energy consumption optimization; a new challenge that GREENERBUILDINGS can face is add some learning mechanisms that infer typical activity patterns characterizing the user.

- **Middleware & compositional approaches:** The eDIANA middleware is also built by exploiting ZigBee profiles and cluster libraries. The latter offer support to the discovery and the addition of new devices making the middleware scalable and adaptable.

- **System architecture:** the modularity approach introduced in eDIANA is definitely a valuable starting point for the definition of the GREENERBUILDINGS architecture.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency		ZigBee				
Scalability				eDIANA	eDIANA	
Privacy						
Costs						
User comfort			Addressed			
Adaptability				eDIANA		
System reliability						
Data security						
Dynamicity		ZigBee				
Standard Compliance		ZigBee				

Table 4.14: eDIANA relations

4.15 SOFIA

4.15.1 Abstract

SOFIA (Smart Objects For Intelligent Applications) [sof] is funded by the European Artemis program under the subprogram SP3 Smart environments and scalable digital services. Central to SOFIA project is the notion of *smart space*. A smart space is an ecosystem of interacting objects. Physically, a smart space is formed by sensors, devices, and appliances that populate the space and it has the capability to self-organize itself. It should also provide services and complex data to (i) a person who physically traverses this space or (ii) a service that queries remotely about the state of the entire space, or part of it. Moreover, a smart space has to be able to elaborate on basic services and raw data to provide orchestrated services or mash-up data to be used by the external world. SOFIA is a 36 months project and it started on January 2009.

4.15.2 Goals

The main goal of SOFIA project is the definition of a platform to support the inter-working of smart embedded services, for creating and managing different smart spaces, through the use of composability and semantic techniques, to guarantee dynamicity, trust and scalability, while preserving privacy if needed. The SOFIA platform should be interoperable (i.e. it should support the interaction and data exchange between multivendor devices) and it should support a range of devices from limited resources to resource-rich devices. Moreover, the SOFIA platform should support a variety of smart spaces and a variety of users. To achieve this goal, SOFIA project is setting up a pilot, showing the interoperability between these domains.

4.15.3 Approach

In order to achieve interoperability, several interaction models are going to be defined to try to characterize all the possible interactions between users' devices and the smart spaces. To that aim, ontologies are defined to model the domains of the various smart spaces and to allow semantic transformation of interaction events and smart objects. Starting from the smart objects, smart services will be defined offering much more usability and effectiveness. Such services will adapt to the user's situation and profile even when they change due, for example, to mobility. To do that, multi-modality and semantic transformation techniques will be adopted. This approach will be concretized in the definition of several scenarios and use cases to demonstrate the capabilities of the SOFIA platform, the proposed interaction models and techno-economic structures in personal spaces, indoor spaces and cities.

4.15.4 Outcomes

The SOFIA project is at the end of the second year and the main outcomes obtained until now can be basically divided in prototypes and scientific publications.

Concerning prototypes, several smart objects have been developed from SOFIA partners. We report here some smart object prototype: *Family Bondind Device* (i.e. a communication device able to capture human presence, and to render this at a remote location to establish a feeling of social connectedness between remote parties), *Spotlight Navigation* (i.e. a generic user interface to configure smart environment based on mobile projection and the flashlight metaphor) *Visual Object Recognizer* (i.e. a compute vision based device to classify and register objects in the smart space).

Concerning scientific publications, SOFIA project largely disseminates its result and a lot of academic paper, industrial and whitepaper are available. Demonstrations are also available and among them we cite the Demo developed Unibo jointly with Eurotech, Nokia, VTT, *Information collected from the environment promotes SOFIAs Smart Applications* presented at the Artemis Autumn Event held in Madrid (Dual SIB - dual Ontology) that received the Artemis exhibition Award.

4.15.5 Relation to GREENERBUILDINGS

SOFIA project does not strictly focus on the building automation context, but some aspects and concepts linked to pervasive computing can be kept from the project and exploited in GREENERBUILDINGS.

- **Building automation & operational services:** smart objects defined in SOFIA can be used to develop the GREENERBUILDINGS "interface", (i.e. the part of the GREENERBUILDINGS platform that provide energy information to the user).
- **Sensors & wireless technology:** in SOFIA ability of the system to react to user mobility is central. Therefore, smart spaces must be able to interact with several heterogeneous wireless devices.
- **Context & activity recognition:** SOFIA uses ontologies to provide a model for a smart space. At the same way, ontologies can be used to model the GREENERBUILDINGS system (e.g. human behaviors).
- **System architecture:** SOFIA aims to define a platform supporting inter-working of smart embedded services to create and manage different smart spaces. To do so, the project plans to use composability and semantic techniques to guarantee dynamicity, trust and scalability, still preserving privacy. The same techniques may be considered in GREENERBUILDINGS to build an interoperable platform.

4.16 E3SoHo

4.16.1 Abstract

The overall objective of E3SoHo project [e3s] is to implement and demonstrate in three Social Housing pilots an integrated and replicable ICT-based solution which aims to bring about a significant reduction of energy consumption in European social housing. This objective follows form the observation that buildings are one of the areas together with Smart Grid and Lighting that offer a high potential for energy savings as they are one of the highest energy consumers (about the 40% of the total energy consumption in Europe).

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency						
Scalability					Sofia	
Privacy					Sofia	
Costs						
User comfort	Addressed					
Adaptability		Smart objects		Sofia		
System reliability						
Data security						
Dynamicity		Smart objects			Sofia	
Standard Compliance						

Table 4.15: SOFIA relations

Within the building sector, residential buildings have the highest environmental impact representing the 63% of total energy consumption in the building sector. Furthermore, the emissions of CO2 from residential buildings are the fourth largest key source of greenhouse gas emissions in the European Union accounting for 10% of total greenhouse gas emissions in 2002. The implementation and testing of ICT solutions in Social Housing will then contribute to get affordable services for reducing the energy consumption and achieving energy efficiency in the Housings.

4.16.2 Goals

The overall objective of E3SoHo project is to bring about a significant reduction of 25% of energy consumption in European social housing by providing tenants with feedback on consumption and offering personalized advice for improving their energy efficiency, reducing the energy consumption and increasing the share of RES (Renewable Energy Sources) by informing and supporting the user to decide for the most appropriate behavior in terms of energy efficiency, cost, comfort and environmental impact, monitoring and transmitting consumption data to Energy Services.

The E3SoHo project aims to the provide a service built up of the following sub-services, that can be provided separately:

- Perform an audit in the building to identify the energy saving potential.

- Provide the owner with an ICT based blue-print to reduce the energy consumption.
- Implement the system according to the blue-print
- Tuning of energy consumption by monitoring
- Maintenance of the installed system.

4.16.3 Approach

The E3SoHo project will combine existing technologies with state-of-the-art developments to provide a holistic solution for an energy efficient social housing sector. The main technological areas contributing to E3SoHo concept are:

- optimized energy management integrating control of the lighting system, of the HVAC system, etc.;
- real-time consumption information of one-family-apartments;
- connection through the Internet for remote control, monitoring, assessment based on collected data, etc.

4.16.4 Outcomes

Because the project was started in 2010, any details of problems happened in its development or deviations from starting objectives are not known at the current state of the project.

4.16.5 Relation to GREENERBUILDINGS

Due to the early stage of the E3SoHo project, the only relation to GREENERBUILDINGS we can deduce is on the objectives.

- **Building automation & operational services:** E3SoHo project aims at the reduction of energy consumption by providing feedback to users and by suggestion actions to save both energy and costs. The monitoring phase is central in the project approach; thus, monitoring mechanisms developed in E3SoHo can be applied in GREENERBUILDINGS too.
- **Context & activity recognition:** E3SoHo does not address explicitly the activity recognition phase. Thus, an additional challenge that GREENERBUILDINGS faces with is the user activity recognition to infer and manage optimally the energy consumption.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency	E3SoHo					RES/ Smart Grid
Scalability						
Privacy						
Costs						
User comfort	E3SoHo					
Adaptability						
System reliability						
Data security						
Dynamicity						
Standard Compliance						

Table 4.16: E3SoHo relations

4.17 Persist

4.17.1 Abstract

PERSIST (acronym for "Personalized Self-improving Smart Spaces") [per] is a research project co-funded by the European Commission under EU Framework Program 7 (FP7); it started in 2008, has a duration of 30 months.
It is based on the concept of Pervasive computing, also called *ubiquitous computing* or *ambient intelligence*. PERSIST project focuses specially on novel solutions to extend Smart Spaces functionalities when merged with other spaces, self-adapting and self-improving, introducing Personal Smart Space (PSS) model. Personal Smart Space concept is based on personal area networks constructed from a variety of networked components, from mobile or wearable devices to smart dust. PSS will be able to provide limited pervasiveness and context awareness at any time and anywhere. Their ability to interoperate with other smart spaces will permit Personal Smart Spaces to automatically adapt environments to satisfy user preferences, to resolve conflicts and to facilitate a migration from smart places to smart regions.

4.17.2 Goals

The objective of PERSIST is to develop Personal Smart Spaces that provide a minimum set of functionalities which can be extended and enhanced as users encounter other smart

spaces during their everyday activities.
The PERSIST infrastructure will be capable of learning and reasoning about users, their intentions, preferences and context. It will be endowed with pro-active behaviors and it will be enabled to share context information with other neighboring Personal Smart Spaces, resolving possible conflicts because of concurrency or incompatible preferences and settings among multiple smart spaces.
Moreover PERSIST will share and balance limited resources between users, services and devices, guaranteeing their own robustness and dependability and protecting users' privacy.

4.17.3 Approach

PERSIST project focuses on many keys features about pervasive and self-adapting aspects:

- interaction with other external Personal Smart Spaces.
- support ad-hoc networks with heterogenous (static and mobile) devices changing dynamically network topology and configuration through the definition of overlay networks.
- adapting and learn through user preferences and context, enabling 3rd party services to adapt and integrate their behavior
- monitoring the user's action applying learning techniques in order to be self improving
- performing context inference and learn new preferences and act proactively based on user intent predictions

4.17.4 Outcomes

The main outcomes of the PERSIST project can be divided in to prototypes and scientific publications.

Concerning prototypes, PERSIST delivered the prototypes for the following architectural components: Prototype of Integrated Networking and Mobility system, Prototype of Context and Preferences, Prototype of Service Discovery and Composition, Dependability and Privacy Prototype Implementation, Prototype Grouping and Sharing Systems, Prototype User Intent System, Prototype Recommender Systems, Prototype Learning and Reasoning Systems and a Prototype for Pro-active Behavior Systems. Moreover, a Personal Smart Spaces (PSS) is available, allowing the creation of a functional Personal

Smart Space. In [KJJ09] it has been proposed a systemic privacy protection framework that changes the way in which the level of regulation is defined and makes it more detailed and concrete. In [LC10] it is described how a context aware architecture has been evolved towards a novel context aware SOA, which provides smart services according to users context. Moreover, it presents a real use case for defining the interactions among the different actors and a description of the architecture.

4.17.5 Relation to GreenerBuildings

PERSIST project does not strictly focus on the building automation context, but some aspects and concepts linked to pervasive computing can be kept from the project and exploited in GreenerBuildings. In particular, we can consider PERSIST's results about system capability of self-configuring, adapting automatically resources and services to users needs.

- **Context & activity recognition:** PERSIST platform makes context information available, to interested parties, by applying intelligent context data retrieval mechanisms based on context semantics and location-based criteria.

- **Middleware & compositional approaches:** In PERSIST the middleware offers support to membership management, group Identification/Discovery/Update and resource sharing through the usage of overlay networks. A privacy preserving component is also included as part of the middleware. The same approach can be followed in GreenerBuildings.

4.18 POBICOS

4.18.1 Abstract

POBICOS [pob] is a research project co-funded by the European Commission under EU Framework Program 7 (FP7). POBICOS aims to design, implement and test a platform that simplifies the task of developing and deploying opportunistic applications in heterogeneous and incompletely specified object collections for the domain of home automation. The main goal of this project is to enable applications to take the best advantage of what-ever 'resource opportunities' exist at runtime, provided by the objects that happen to be available, transparently to the programmer.
POBICOS is a 36-month project, and it started on May 2008.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency	Personal Smart Spaces					
Scalability				Personal Smart Spaces		
Privacy				Personal Smart Spaces		
Costs						
User comfort						
Adaptability				Personal Smart Spaces		
System reliability						
Data security						
Dynamicity				Personal Smart Spaces		
Standard Compliance						

Table 4.17: PERSIST relations

4.18.2 Goals

To build ubiquitously deployable applications, the programmer must write applications which are able to automatically exploit whatever opportunities (i.e. sensor, actuator and computing resources) happen to be available at any given setting.

Moreover, these opportunities should be sought as to meet both functional and non-functional requirements of the application in the best possible way, scaling gracefully as a function of which and how many of the required resources are available.

For example, it could be possible to accomplish a given task not just with a pre-specified sensor or actuator, but with any one or more instances belonging to the same of a compatible resource class. Similarly, to minimize energy consumption of battery-powered nodes, processing intensive tasks could be transferred to nodes with ample energy supply and appropriate computing resources.

The goal of the project is to actively research and offer support for *opportunistic pervasive computing applications* by building a platform that enables the easy programming of partially unknown, heterogeneous object communities, and which addresses the key phases of the application lifecycle: development, deployment, and runtime.

4.18.3 Approach

The research focus of the POBICOS project can be summarized in these main activities[1]:

1. The design of a programming model and supporting mechanisms for opportunistic pervasive computing
2. An ontology-driven approach for modeling and flexibly accessing resources for a given application domain
3. The implementation of a corresponding middleware on top of embedded wireless sensor/actuator nodes
4. The provision of suitable resource abstraction and domain-based customization tools as well as application development, simulation and deployment tools
5. The experimental validation of the middleware and tools for a selected application domain in the area of home automation

The domain of energy efficiency at home have been used as the source of scenarios and requirements.

4.18.4 Outcomes

Actually, the main outcome of the POBICOS project seems to be the release of the middleware as open source product.

The middleware has been developed by combining three main technical dimensions in a tightly coupled fashion: (i) Ontology-driven multi-resolution representations of sensors and actuators; (ii) Abstractions and mechanisms for physical node transparency; (iii) Concepts, mechanisms and tools for security, privacy and deployment.

POBICOS uses ontologies to capture concepts of a given domain and enable resource access at the desired level of abstraction/detail.

Each application running on POBICOS represents some goal. Its achievement is facilitated by the middleware mechanisms to find, combine, and exploit proper resources of the object community. Moreover, it can be packaged into a small hardware unit, which the user activates at any point in time. As a result, the middleware spreads the application's micro-agents to the objects with the suitable resources found in the environment.

[1]Because of early state of project, many details on implementation have not been found.

4.18.5 Relation to GREENERBUILDINGS

- **Building automation & operational services:** In POBICOS special attention has been devoted to the development of simplified energy-saving applications into peoples home with the final goal of building a platform usable also by not technical people. This issue is also important in the GREENERBUILDINGS's context (i.e. building automation). Differently from a house, a building is populated by a lot of different people, with different level of expertise; thus, providing flexible mechanisms to interact with the platform, independently from the technical skills of each user, is a mandatory task.

- **Middleware & compositional approaches:** POBICOS middleware has been developed by defining concepts, mechanisms and tools for security and privacy. Some privacy preserving mechanism implemented in the POBICOS middleware can be exploited by the GREENERBUILDINGS platform.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency						
Scalability						
Privacy				POBICOS middleware		
Costs						
User comfort	Addressed					
Adaptability						
System reliability						
Data security						
Dynamicity						
Standard Compliance						

Table 4.18: POBICOS relations

4.19 REViSiTe

4.19.1 Abstract

REViSITE [owpi] is funded by the European Commission under the Seventh Framework Programme and the duration is 2 years starting from 1st February 2010. REViSITE contributes to the formation of a European multidisciplinary 'ICT for energy-efficiency' research community by bringing together the ICT community and four important and complementary application sectors: Smart Grids, Smart Buildings, Smart Manufacturing and Smart Lighting.

4.19.2 Goals

The objectives of REViSITE are to:

1. Establish communication between sectoral ICT4EE communities in the four key industrial domains
2. Develop causal models on the impacts of ICT on energy efficiency and apply this methodology for identifying high-impact RTD priorities
3. Develop a cross-sectoral RTD roadmap by identifying and harmonizing common topics
4. Promote interoperability and standards
5. Raise awareness

4.19.3 Approach

The REViSITE project co-ordinate co-operation and communication within the ICT4EE research community in Europe. The core of this community will be formed from the European Technologies Platforms (ETPs) that represent RTD in these sectors: ARTEMIS, ECTP, MANUFUTURE, PHOTONICS21, SMARTGRIDS.

REViSITE will identify complementarities between the four target sectors: grids, buildings, lighting and manufacturing in the area of ICT for energy efficiency (ICT4EE), harmonizing common RTD priorities for ICT4EE in the four sectors, and establishing a cross-sectoral "community" with links to different industry sectors and related ETPs.

REViSITE will develop a causal model of how ICT can impact on energy consumption in 4 key sectors. Based on available statistical data and, where such data is not available, estimations by experts, the project aims to identify RTD priorities for ICT4EE.

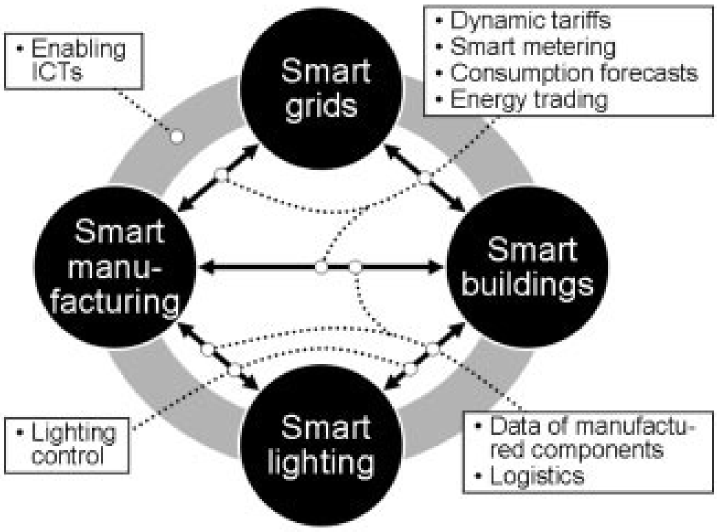


Figure 4.4: REViSITE Approach

The project will engage key stakeholders from the 4 sectors via a 'focus group' and a dedicated concise 'expert group' to compare and analyze sector specific RTD agendas such as Strategic Research Agendas (SRAs) of the relevant European Technology Platforms (ETPs), European and national RTD initiatives etc. A consolidated roadmap will be derived as a synthesis. This will catalyze synergetic RTD and innovation in multiple sectors by pointing to cross-sectoral RTD opportunities in common areas of interest that have the highest potential impact.

4.19.4 Outcomes

The project has started in February 2010 and the current state of the project very few details are available.

4.19.5 Relation to GreenerBuildings

The project shares with GreenerBuildings some aspect of the vision, that is the energy efficiency objective, considering energy-smarter buildings (e.g. smart lighting) and an improvement in the use of the resources, both in new buildings and in renovated buildings. Anyway the project is more oriented on general aspects such as grid balancing and not at a single building level. Moreover the project is mainly focused on ICT and its impact on energy consumption.

Very few aspects could be considered and reusable in the GreenerBuildings project. Smart lighting for example is also present in GREENERBUILDINGS but in this project an intelligent light management system is not yet available as the project is at an early stage.

- **Smart grid:** the stability of the power grid and the standardization of the data exchange is a key point in the smart grid, one of the action of REViSITE is to evaluate and identify existing and lacking interoperability frameworks and needs for convergence of standards, (e.g. data exchange standards) this aspect can be reasonably considered in the developed GREENERBUILDINGS project, in particular the causal model developed on how ICT can impact on energy consumption.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency						ICT Causal Model
Scalability						
Privacy						
Costs						ICT Causal Model
User comfort						
Adaptability						
System reliability						
Data security						
Dynamicity						
Standard Compliance						

Table 4.19: REViSITE relations

4.20 HYDRA

4.20.1 Abstract

The Hydra project [owpc] is a 4-year Integrated Project that develops middleware for Networked Embedded Systems and is co-funded by the European Commission within the Sixth Framework Programme.

The Hydra middleware allows developers to incorporate heterogeneous physical devices into their applications by offering easy-to-use web service interfaces for controlling any type of physical device irrespective of its network technology such as Bluetooth, RF, ZigBee, RFID, WiFi, etc. Hydra incorporates means for Device and Service Discovery, Semantic Model Driven Architecture, P2P communication, and Diagnostics. Hydra enabled devices and services can be secure and trustworthy through distributed security and social trust components of the middleware.

4.20.2 Goals

The first objective of the Hydra project is to develop middleware based on a Service-oriented Architecture, to which the underlying communication layer is transparent. The middleware includes support for distributed as well as centralized architectures, security and trust, reflective properties and model-driven development of applications.

The HYDRA middleware is deployable on both new and existing networks of distributed wireless and wired devices, which operate with limited resources in terms of computing power, energy and memory usage. It allows for secure, trustworthy, and fault tolerant applications through the use of distributed security and social trust components. The embedded and mobile Service-oriented Architecture provide interoperable access to data, information and knowledge across heterogeneous platforms, including web services, and support true ambient intelligence for ubiquitous networked devices.

The second objective of the HYDRA project is to develop a Software Development Kit (SDK). The SDK will be used by developers to develop innovative Model-Driven applications.

4.20.3 Approach

Physical devices are the cornerstone of any application intending to implement the Hydra middleware. Any application using external devices such as energy meters, light control switches, blood pressure monitors, etc., will need to interface with the device through its communication interface, which will be greatly facilitated by using the Hydra middleware. A Hydra-enabled device contains a software representation in the network and can be discovered by other devices and make its functions accessible as Web Services to the application. At the end of October 2010 42 devices have been Hydra-enable, in particular:

- Medical and wellness devices
- Energy Devices
- Physical Properties Devices
- Media and Videos Devices
- Network and Gateways Devices

4.20.4 Outcomes

The project results consist of the following end products:

- HYDRA middleware for networked embedded systems - Adds AmI applications to new and existing embedded systems and components.
- HYDRA Software Development Kit (SDK) for middleware - Allows developers to rapidly create new networked embedded AmI applications.

The middleware supports cost-effective and innovative embedded systems applications for new and already existing devices, which operate with limited resources in terms of computer power, energy and memory usage. The Software Development Kit (SDK) will allow developers to develop the innovative software applications with embedded ambient intelligence computing using the middleware.

4.20.5 Relation to GREENERBUILDINGS

HYDRA Project has very few aspect connected with GREENERBUILDINGS. Anyway the outcomes that derive from the project can be taken into consideration. In particular HYDRA middleware can be better analyzed and reused for the ubiquitous devices. The middleware is also scalable and has been successfully applied into different sectors, this is a key point considering that GREENERBUILDINGS has the objective to be addressed to different kind of buildings (e.g. offices,hospitals, hotels). Moreover the web service approach can be considered and the Open Source reference implementation will be soon available on SourceForge.

- **Sensors & wireless technology:** One of the objective of the Hydra middleware is to control any type of physical device irrespective of its network technology such as Bluetooth, RF, ZigBee, RFID, WiFi, etc.
- **Middleware & compositional approaches:** The HYDRA middleware is deployable on both new and existing networks of distributed wireless and wired devices, which operate with limited resources in terms of computing power, energy and memory usage. It allow for secure, trustworthy, and fault tolerant applications through the use of distributed security and social trust components.
- **System architecture:** In the great amount of heterogeneous devices, sensors, and actuators with embedded systems existing HYDRA middleware implement and exploit the intelligence embedded in the devices.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency						
Scalability				HYDRA Middleware	HYDRA Middleware	
Privacy						
Costs						
User comfort						
Adaptability				HYDRA Middleware	HYDRA Middleware	
System reliability						
Data security				Distributed security and social trust components		
Dynamicity						
Standard Compliance		Bluetooth, RF, ZigBee, RFID, WiFi, etc				

Table 4.20: HYDRA relations

4.21 Thermco

4.21.1 Abstract

ThermCo [owpm] is a project funded by the European Commission within the Intelligent Energy Europe programme. ThermCo provides consistent design guidelines and legal certainty for low-energy cooling:

- evaluates low-energy cooling concepts all-over Europe using a standardized method based on existing monitoring data from good and best practice examples
- provide design guidelines for typical building concepts in the European climate zones
- collect the knowledge available and transfers it into a REHVA Guidebook on Low-Energy Cooling in Europe which acts as a commonly accessible knowledge pool for passive and low-energy cooling techniques

High performance buildings have shown that it is possible to go clearly beyond the energy requirements of existing legislation and obtaining good thermal comfort.

4.21.2 Goals

Thermco aims to identify the conditions for achieve good indoor environment in summer with low energy supply. To this end other objectives are:

- guidebook on Low-Energy Cooling and Thermal Comfort
- provide recommendations for further development of EN 15251
- establishing an annex for EPBD-related CEN-standards for buildings with high energy efficiency and good indoor environment.

4.21.3 Approach

ThermCo's approach is implemented through five steps:

- **Data evaluation:** Compilation, acquisition and evaluation of existing monitoring data from typical, low-energy and high-performance office buildings in Europe
- **Application:** Identification and evaluation of different measures for low energy demand and high indoor environmental quality in different European climate zones
- **Regulatory measures:** Collection of available knowledge and transferring it into a guideline which acts as a commonly accessible knowledge pool for passive and low energy cooling techniques
- **Demonstration:** The proposed approach is applied to eight demonstration projects in different climatic zones of Europe in order to test, to validate and, if necessary, to revise the evaluation procedure
- **Dissemination:** Preparation of appropriate information material for the different target groups involved in the design and planning process of buildings.

4.21.4 Outcomes

The outcomes of the project are:

- A guidebook on Low-Energy Cooling and Thermal Comfort; This Guidebook will contribute to reduced cooling energy demand, better indoor environment and cost-effective building concepts

- provide recommendations for further development of EN 15251
- establishing an annex for EPBD-related CEN-standards for buildings with high energy efficiency and good indoor environment

4.21.5 Relation to GREENERBUILDINGS

The main elements that can be taken in consideration by GREENERBUILDINGS are mainly associated with the approach, based on the analysis of the building by different point of view (i.e. user comfort, energy savings) :

- **Sensors & wireless technology:** measurement campaign of environmental parameters related to thermal comfort (long-term measurements in combination with field studies on thermal comfort); measurement campaign on several test cases in different climatic zones
- **Context & activity recognition:** simulation studies on thermal comfort and air conditioning systems were performed using dynamics simulations of building model in TRNSYS

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture Ł	Smart Grid
Energy efficiency		Measurement Campaign Approach	TRNSYS Simulations			
Scalability						
Privacy						
Costs						
User comfort		Occupant Satisfaction Analysis	TRNSYS Simulations			
Adaptability						
System reliability						
Data security						
Dynamicity			TRNSYS Simulations			
Standard Compliance						

Table 4.21: THERMCO relations

4.22 Casas Project

4.22.1 Abstract

The CASAS Smart Home project [owpb] is a multi-disciplinary research project at Washington State University focused on the creation of an intelligent home environment. The approach is to view the smart home as an intelligent agent that perceives its environment through the use of sensors, and can act upon the environment through the use of actuators.

4.22.2 Goals

CASAS project has certain overall goals, such as minimizing the cost of maintaining the home and maximizing the comfort of its inhabitants. In order to meet these goals, the house must be able to reason about and adapt to provided information.

4.22.3 Approach

The project is implemented through the following steps:

- Identification of trends and anomalies in smart home sensor data
- Activity recognition
- Activity tracking and assessment
- Multiple resident profiling
- Robotic interventions in smart homes
- Monitoring exercise habits in smart homes
- Estimating energy usage in smart homes

4.22.4 Outcomes

CASAS projects collect a very wide range of problems. The results of the project are related to the development of methods for the recognition of activities, the effects on occupants and the application of these methods in specific cases. The project also provides the tools for evaluation and visualization of the occupants.

A good collection of publications related to the project is available from 2005.

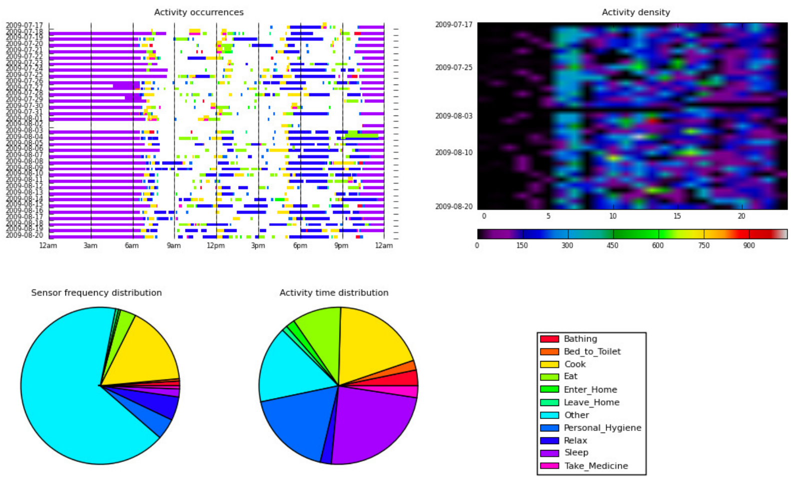


Figure 4.5: Activity Code

4.22.5 Relation to GREENERBUILDINGS

The relationship of the project Casas with GREENERBUILDINGS is strong for multiple purposes. Common features are related to the use of sensors and actuators that identify the building (in Casas Project the attention is focused on the houses) as an intelligent agent. Main actions:

1. activity recognition of the occupants (see activity recognition code)
2. identification of trends and anomalies in smart home sensor
3. evaluation of the energy in smart home

GREENERBUILDINGS Relations

- **Sensors & wireless technology:** Different kind of sensors have been used, for example key sensors and motion sensors, and this aspect and method can be considered as reusable into GREENERBUILDINGS
- **Context & activity recognition:** Recognition and context of the house is a focus point in Casas Project, and a code has been developed (AR Activity Recognition Code V1.2 and AV Activity Visualization Code)

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture Ł	Smart Grid
Energy efficiency						
Scalability		key and motion sensors	AR & AV Code			
Privacy						
Costs						
User comfort			AR & AV Code			
Adaptability						
System reliability						
Data security						
Dynamicity		key and motion sensors	AR & AV Code			
Standard Compliance						

Table 4.22: CASAS Project relations

4.23 EcoSense

4.23.1 Abstract

The EcoSense project [New] is a joint initiative of the i3A, the Albacete Research Institute of Informatics and AGECAM, the regional Energy Agency of Castilla La Mancha funded by the Council of Science and Innovation of Castilla La Mancha. The EcoSense project aims to monitor all devices consuming energy in an intelligent building. First deploying a network only with sensors (temperature, humidity, luminosity, electrical consumption, presence detectors). Second adding an upper layer of manager agents (actors) to communicate and negotiate services.

4.23.2 Goals

Energy efficiency has been identified as a priority area by the European Commission. The main objective of the EcoSense project is to develop a methodology for the design and deployment of monitoring [PR10] and control environmental indoor systems built around wireless sensor and actuator networks.

During the first phase of the project, the research efforts are being focused on the monitoring capabilities of a collaborative set of environmental monitoring devices. The results of this first phase should set the basis towards the understanding of the capabilities and main issues to be addressed for the effective deployment and operation of a set of sensors and actuators in indoor infrastructures. In a second phase, the system will be equipped with intelligent actuators enabling the optimal configuration and operation of energy consumption control systems. These actuators will be agents with capabilities including goal management and task execution. These agents will be able to communicate and negotiate services to achieve the required functionality.

4.23.3 Approach

On the design of energy saving systems, there are several factors that have to be considered and studied carefully: temperature outdoors and indoors, luminosity, electrical consumption and presence detectors (passive infrared detectors, door and window opening sensors).

The main variable in energy control is room temperature, since a comfortable working environment, and the energy consumed by the air conditioning in cooling the room, or by the heaters, depends to a great extent on this factor. The correct monitoring of the room temperature as perceived by the workers requires a wise layout of the monitoring devices. It is well known that measuring the temperature at one point within a room may not provide a representative view of the environmental conditions.

However, the simple replication of multiple monitoring temperature sensors may neither overcome this issue. Furthermore, the monitoring of the outdoor environmental conditions may also play a major role on the optimization of an energy-aware monitoring and control system.

4.23.4 Outcomes

A smart wireless sensor network [PD11] has been developed and is available; the devices are the embedded system MTM-CM5000-MSP made by Maxfor Technology INC.

4.23.5 Relation to GreenerBuildings

EcoSense project has similar objectives with GreenerBuildings aiming at energy saving and occupant comfort. Some aspect can be considered for GreenerBuildings related to the environment observation, both indoor and outdoor, and to the methodology in designing and deploying wireless sensor network.

- **Building automation & operational services:** addition of actors to the wireless sensor network in order to improve energy saving

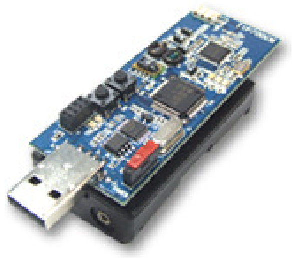


Figure 4.6: MAXFOR Sensor Node

- **Sensors & wireless technology:** deployment of a small wireless sensor network in a room of the building and analysis of the results. EcoSense analyses and implements IEEE 802.15.4 protocol and supports TinyOS. The network can be extended to cover the whole building.
- **Context & activity recognition:** The network is used to infer the context of the building by measuring temperature, light and humidity (these sensors are embedded in the main board)
- **Middleware & compositional approaches:** In EcoSense the actors may be agents with capabilities including goal management and task execution, and this is similar to the GREENERBUILDINGS where the actuators can operate physically on the building to optimize the energy consumption and the comfort of the occupants.

4.24 OPPORTUNITY

4.24.1 Abstract

OPPORTUNITY [owpg] is a project that deals with activity and context recognition.

The main objective is to develop opportunistic systems that recognize complex activities/contexts despite the absence of static assumptions about sensor availability and characteristics.

These systems are based on goal-oriented sensor assemblies spontaneously arising and self-organizing to achieve a common activity/context recognition goal. They are embodied and situated, relying on self-supervised learning to achieve autonomous operation. They make best use of the available resources, and keep working despite, or improves thanks to changes in the sensing environment. Changes include e.g. placement, modality, sensor parameters and can occur at runtime.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency	EcoSense Actors	Maxfor node	Maxfor node	EcoSense Actors		
Scalability		Maxfor node	Maxfor node			
Privacy						
Costs						
User comfort						
Adaptability						
System reliability						
Data security						
Dynamicity						
Standard Compliance		IEEE 802.15.4, TinyOS				

Table 4.23: EcoSense relations

4.24.2 Goals

The objective of this project is to develop mobile systems to recognize human activity and user context with dynamically varying sensor setups, using goal oriented, cooperative sensing. These systems have been defined opportunistic, since they take advantage of sensing modalities that just happen to be available, rather than forcing the user to deploy specific, application dependent sensor systems.

This project is grounded in wearable computing and pervasive/ubiquitous computing or Ambient Intelligence (AmI). The vision of AmI is that of pervasive but transparent technology, always on, always present, that provides the appropriate information, assistance and support to users at appropriate moments, proactively and in a natural way. The key mechanism to achieve this is to recognize the user's activities and the user's context from body-worn and ambient sensor-enabled devices, in order to infer automatically when, how, and by which modality to support the user.

OPPORTUNITY aims to develop a novel paradigm for context and activity recognition that will remove the up-to-now static constraints placed on sensor availability, placement and characteristics. This is in contrast to most state of the art approaches that assume fixed, narrowly defined sensor configurations dedicated to often equally narrowly defined recognition tasks.

4.24.3 Approach

OPPORTUNITY includes ad-hoc cooperative sensing to obtain data about the user and surrounding world; a flexible and parameterizable opportunistic recognition chain; and runtime supervision and adaptation methods to opportunistically cope with changes.

- Ad-hoc, cooperative sensing: A mobile device opportunistically exploits information from sensors placed in the users outfit, in the environment and other sources of information to recognize contexts/activities. Sensors are opportunistically interconnected and enable large scale data acquisition about the user and the world surrounding him.
- Opportunistic context recognition chain: The opportunistic context recognition chain is adjustable at all levels (signal pre-processing, feature extraction, classification, decision fusion, higher level processing), in contrast to traditional approaches. The number and parameters of sensors, features, or classifiers used can be dynamically adjusted according to the performance goal.
- Adaptation: A key element of the opportunistic approach is dynamic adaptation and autonomous evolution on the basis of self-supervision and system/user feedback. Self-supervision and feedback, with corresponding adaptation strategies, enable to control the parameters of the opportunistic context recognition chain to adapt it to the sensor configuration at hand. This enables rapid dynamic adaptation to spontaneous changes in sensor configurations as well as long term autonomous evolution to gradual changes in sensing environments and users.

4.24.4 Outcomes

Specific outcomes include:

- Spontaneous goal-oriented sensing ensembles
- Robust abstract intermediate features
- Novel opportunistic classifiers and opportunistic classifier fusion
- Dynamic -short-term- adaptation of the activity recognition chain
- Autonomous -long-term- evolution of the activity recognition system
- Advances in Opportunistic robust Brain-Computer Interfaces

Application-wise, outcomes are activity and context recognition systems providing the following characteristics: (1) working over long periods of time despite changes in sensing infrastructure (sensor failures, degradation); (2) providing the freedom to users to change wearable device placement; (3) that can be deployed without user-specific training.

4.24.5 Relation to GreenerBuildings

One of the objective of OPPORTUNITY is strongly connected with GreenerBuildings, that is the context activity recognition. One of the aspect that can be considered could be reuse of the opportunistic systems. Moreover the validation of the scenarios can be evaluated.

Validation Scenarios:

1. simple activities are considered, such as manipulative gestures
2. composite activities are considered, such as manipulative activities occurring simultaneously as other whole body physical activities
3. finally complex activities taken from real-world scenario (indoor activity recognition, health and wellness oriented activity monitoring) are considered.
4. Methods are demonstrated on a complex cognitive context recognition task (EEG-based Brain-Computer Interfaces). Opportunistic BCI systems will be tested on experimental protocols ranging from the detection of evoked and event-related potentials linked to the user cognitive state, to the recognition of user modulated brain rhythms.

GreenerBuildings Relations

- **Sensors & wireless technology:** Accelerometers, gyroscopes, magnetometers and inertial sensors (on-body and in instrumented objects) Beacon systems (Bluetooth, active RFID), UWB systems and GPS for localization, instrumented appliances, sockets, switches, and presence detection for ambient intelligence, microphones (on-body and ambient) for activity recognition.
- **Context & activity recognition:** Opportunity uses opportunistic sensor configurations relying on self-supervised learning to achieve autonomous operation. They make best use of the available resources, and keep working despite, or improves thanks to changes in the sensing environment.
- **System architecture:** Opportunistic systems that recognize complex activities/-contexts are based on goal-oriented sensor assemblies spontaneously arising and self-organizing to achieve a common activity/context recognition goal. They are embodied and situated, relying on self-supervised learning to achieve autonomous operation.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency						
Scalability		Different kind of sensors			Opportunistic system	
Privacy						
Costs						
User comfort						
Adaptability			Opportunistic Sensor Configurations			
System reliability						
Data security						
Dynamicity		Different kind of sensors	Opportunistic Sensor Configurations		Opportunistic system	
Standard Compliance		Bluetooth, active RFID, UWB, GPS				

Table 4.24: OPPORTUNITY relations

4.25 Enprove

4.25.1 Abstract

The FP7 EnPROVE project, [enP] which started in 2010, looks into how to predict the energy consumption of a specific building, with different scenarios implementing energy-efficient technologies and control solutions, based on actual measured performance and usage data of the building itself. The key hypothesis of EnPROVE is that it is possible, from adequate gathering and assessing data on how a structure performs and is being used by its occupants from an energy viewpoint, to build highly accurate and specific energy consumption models relevant for prediction of alternative scenarios. The EnPROVE software tools assess the energy efficiency impact of alternative technologies for which available investment resources can be directed and, thus, support the decision maker finding the optimized set of energy-efficient solutions to be implemented. These results are tailored to the actual building itself, through automated measurements of building usage and energy consumption.

4.25.2 Goals

The project argues that, to date, the market lacks a monitoring system that is able to assess the full life-cycle energy associated with new products, processes and services before their realization and including the influence of users' interaction. The main goal for EnPROVE is to bridge that gap and provide an enterprise management system to extend existing building design tools with energy features that are able to predict the energy consumption of a structure prior to retrofitting an energy saving solution and to make recommendations for the best control system to install. The EnPROVE system is foreseen as a tool that will be able to compare different control strategies or systems energy saving impact on a given user behavior and environmental scenario.

The EnPROVE software tools will assess the energy-efficiency impact of alternative technologies for which available investment resources can be directed and, thus, support the decision maker finding the optimized set of energy-efficient solutions to be implemented. These results will be tailored to the actual building itself, through automated measurements of the building usage and energy efficiency. Technological solutions will include energy-reducing, -generating, and storing options, and with user-defined criteria on resources and restrictions, will identify through new prediction algorithms when the return on investment will be realized.

4.25.3 Approach

The EnPROVE approach is based on the monitoring of the building usage by a wireless sensor network to build adequate energy consumption models. These models are then used to predict the impact on energy consumption of the eventual installation of several energy efficient technologies. Finally, the decision-support model suggests the best investment alternative taking into consideration the investor criteria and possible restrictions. As shown in the figure below, EnPROVE consists of two main modules: an Energy Prediction Support System (EPSS) and a Building Performance and Usage Auditing Wireless Sensor Network.

This system acts as a tool to compare different control strategies on a given user behavior and environmental scenario to provide accurate energy consumption prediction and recommendations prior to investing in energy saving system installation. The approach will take the following factors into account in its design and workflow implementation:

- Enhancing existing CAD and Facility Management (FM) tools with energy features to make easier the integration of the energy management system from the initial stages of the building refurbishment process and will assess the full life cycle of energy-saving services before their realization and including the influence of users interaction. This tool will also be used to define energy management patterns, user profiles, methods, energy consumption models and their interrelations resulting in building blocks for applications interoperable with existing tools for building design and modeling, such as CAD systems. - Its services will allow assessing the full life cycle of energy-saving solutions before their realization and including the influence of users interaction.

- Facilitating a cheaper and a more energy efficient installation of control systems by providing energy prediction and decision making support for several parts of the structure.

- Unobtrusive and easy to deploy wireless sensor network installed for a certain amount of time to gather specific information about the building.

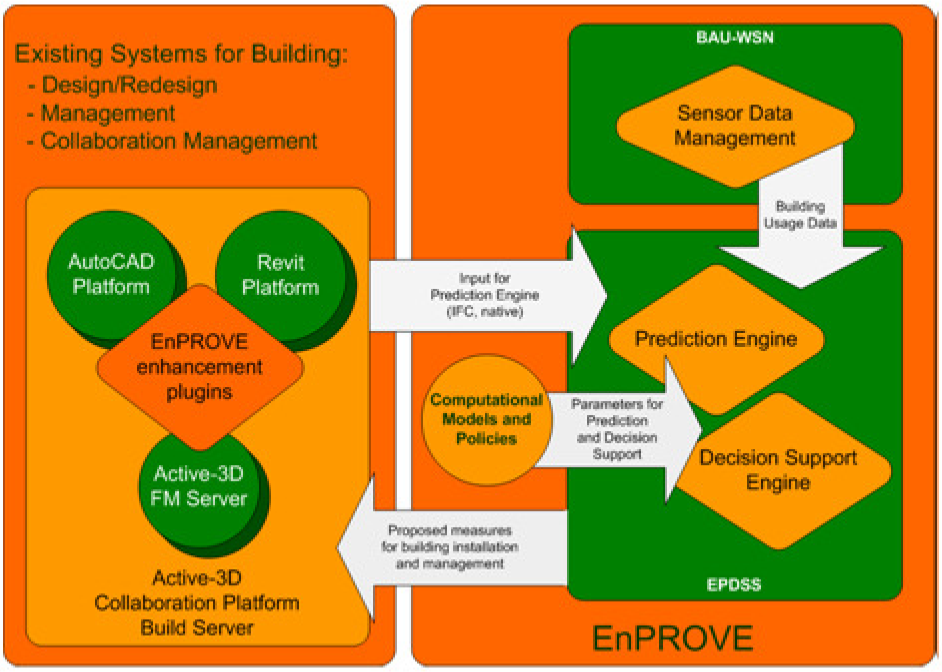
- The calculation of the profit for deploying control systems includes CO2, lighting, and heating habits of the user related to the monitoring scenarios.

- Providing a powerful sales tool for installation companies to predict customers return on investment (ROI) for the market of existing buildings. This would be based on building utilization and user habits in several parts of the building.

- Identification of parts of the building responsible for major energy wastage that may assist a suitable renovation plan.

4.25.4 Outcomes

The outcomes of the project will consist of software tools that can plug into existing building design and management solutions as well as a prediction engine and decision support engine that can interface with building usage data (from available sensors). Another outcome of the project will be the applications and services that can sit on top of such a solution. These services will open new business opportunities for both construction companies that work on building renovation, as well as building management companies on long-term contracts. The application of the tools will be validated in two real buildings.



4.25.5 Relation to GREENERBUILDINGS

Since the basic framework is based around sensing, predicting and deciding around energy related scenarios, there are several points of intersection with the GREENERBUILDINGS project:

- **Building automation & operational services:** The initiative is driving in these areas. Costs and ROI are clear boundary conditions for EnPROVE that will be factored into the decision support. The types of building operational services and building automation strategies may have some overlap with GREENERBUILDINGS.

Energy efficiency is the primary driver for both projects, however, it is not clear if EnPROVE will address user comfort metrics as part of its prediction/decision architecture.

- **Sensors & wireless technology:** The WSN interface as offered as part of the EnPROVE system architecture will likely leverage on existing standards. Also guidelines will be provided on how to select the appropriate size and configuration of the sensor network (note that the WSN is only required to be present until decision support outcomes are derived).

- **Context & activity recognition:** Since the predictive element of the solution must process and contextualize incoming building data, there is a strong overlap with context and activity recognition (especially from a data mining perspective). Monitoring building usage can be seen as looking at users (in particular user behavior). One of the distinctions here though is that the architecture is not necessarily real-time capable since many of the decision points are present offline via the tooling support.

- **System architecture:** Physical modeling is a clear part of the system solution. However it is not likely that the solution will be linked to a run-time simulation/sensing solution.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency	Addressed		Energy consumption models		Energy consumption models	
Scalability						
Costs	Addressed					
User comfort	Addressed					
Adaptability						
System reliability						
Dynamicity						
Standard Compliance	WSN interface				WSN interface	

Table 4.25: EnProve relations

4.26 Aware home

4.26.1 Abstract

The Aware Home Research Initiative at Georgia Institute of Technology

[Awa] investigates the possibilities of creating a home environment that is aware of its occupants whereabouts and activities. In addition to looking into the technologies needed to develop aware environments (including sensing technologies), the initiative looks into possible applications that the state-of-the-art cannot readily support, such as health and wellness at home (aging, health IT, ..) and sustainability.

4.26.2 Goals

The goals of the aware home initiative are to innovate in three areas: Home Care; Future Tools for the Home and Digital Entertainment. The goals around each of these areas all exploit awareness systems with intuitive and advanced forms of interaction technology (including robots). For home care, a variety of research projects aim to exploit on-body biomechanical and medical sensing for elderly care (e.g. medication compliance), but there is no explicit goal to derive a consistent platform across such applications. Usability factors, ergonomics and (social) psychological factors are also an integral part of achieving project the goals within the initiative. As part of this, a series of living labs has been set up (e.g. to assess scalability requirements for home health applications, or to perform longitudinal studies in senior living towers to derive a clinical understanding of user needs).

4.26.3 Approach

The Aware Home Research Initiative has approaches awareness technologies using the following methods:

- Empirical studies of home-based health management practices, including chronic disease care and healthy lifestyle adherence
- Interactive tools that promote health education and care by utilizing sophisticated home health monitoring
- Visualizations and ambient display techniques to present health monitoring results in a way appropriate for the home
- Understanding home support needs of older adults
- Developing a framework for technology acceptance concerns, especially those around privacy and automation issues

- Investigating the impact of in-home energy consumption displays
- Investigating the needs of separated family members using tele-presence technologies
- How to design robotic products that fit into the home, do meaningful work there, and are desirable to own
- New tools for capturing and organizing the meaningful moments of everyday life, and then facilitating storytelling using these captured media
- Mechanisms for easy content sharing between homes for example, to allow secure photo sharing among family members that are at a distance from one another
- New forms of network gaming, including games that promote well-being such as exercise-based games
- Prototype new media streaming architectures and applications, to allow easy access to purchased or self-created content throughout the home
- Interactive tools to facilitate easier control over media devices in the home
- Empirical studies of homeowners needs and desires with respect to home entertainment and media.

4.26.4 Outcomes

Several of the research projects described in the initiative do not seem to lead toward a single platform approach to aware systems, but are more inter-disciplinary solutions that are tailored to specific social needs in a home context. However, the use of the Georgia Tech Broadband Institute Residential Laboratory, a three-story, 5040-square-foot home that functions as a living laboratory enables researchers to place their solutions in the context of other results.

4.26.5 Relation to GreenerBuildings

There are several touch points with regard to sensing technologies and energy management, but most of the application and architecture is too home-centric with application foci that do not scale well when considering large scale automation with energy and public spaces.

- **Building automation & operational services:** Several examples are shown of building automation, but these are mainly oriented towards residential buildings.

- **Sensors & wireless technology:** Many examples of the use of sensors and wireless technologies.
- **Context & activity recognition:** Several of the projects within the initiative share a common middleware to abstract the sensor network for awareness information to a virtual sensor (e.g. for use in a remote management system).
- **Middleware & compositional approaches:** There are several examples of such approaches, such as in the home health domain, but these tend to be tailored to the application and are not directly re-usable.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency						
Scalability		Addressed			Addressed	
Privacy						
Costs						
User comfort	Addressed					
Adaptability						
System reliability						
Data security				Addressed		
Dynamicity			Addressed			
Standard Compliance						

Table 4.26: Aware Home relations

4.27 Dehems

4.27.1 Abstract

The Digital Environment Home Energy Management System project [Deh] is an FP7 project that started in 2009 looking at how technology can improve domestic energy efficiency. The project partnership includes a mix of European local authorities, private business and universities. The intention is to develop and test a home energy management system for the home market using Living Labs in 5 cities across Europe to improve the current monitoring approach to levels of energy being used by households, with an overall aim of reducing CO2 emissions across Europe.

4.27.2 Goals

DEHEMS aims to extend the current state of the art in intelligent meters, moving beyond energy input models that monitor the levels of energy being used to an energy performance model that also looks at the way in which the energy is used. Bringing together sensor data in areas such as household heat loss and appliance performance as well as energy usage monitoring, it offers real time information on emissions and the energy performance of appliances and services. In turn the potential exists to make changes to appliances/services remotely from the mobile phone or PC. The system can also provide specific energy efficiency recommendations for the household. The potential is to personalize action on climate change, and so help enable new policies such as Personal Carbon Allowances as well as supporting the move towards increased localized generation and distribution of energy.

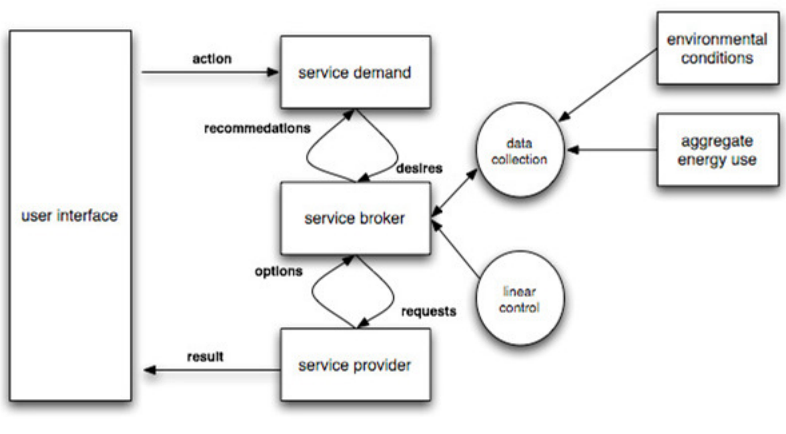
4.27.3 Approach

The Dehems project is split up into the following work packages: User Requirements and System Architecture; Semantic Services Development; Control Systems Development; Energy Measurement; System Integration and Living Labs Validation and Analysis.

The DEHEMS system is being developed using the Living Labs model over three cycles. This tests the impact of the system in the real world environment through user and community feedback. Cycle 1 was the starting point for the system composition and interaction. The experience gained in the UK Living Labs within the first cycle has been used to introduce two Living Lab test-beds in Bulgaria.

4.27.4 Outcomes

The overall system solution is specifically tailored to residential energy management applications as shown in the figure below:



From such a solution in the context of a living labs implementation, The outcomes of the project consist of:

- A set of UI guidelines for offering energy and environmental feedback and control
- A list of devices and semantic-based services that can be used in the implementation of the SANET (sensor and actuator network)
- A reference model and pattern analysis engine for measuring and predicting energy consumption

4.27.5 Relation to GREENERBUILDINGS

Although some of the requirements regarding energy measurement and occupant behavior appear to have some similarities, Dehems focus on residential buildings means that there are many large differences in user requirements, technical challenges and viable system solutions. Having said this, there may be some overlap regarding the use of wireless technologies and sensor technologies. Further, the advanced metering infrastructure will likely serve smart grid interconnectivity.

- **Building automation & operational services:** Mainly linked to user interfaces with services tailored around these, with limited use of actuators.
- **Sensors & wireless technology:** More about using existing WSAN technologies than innovating.
- **Context & activity recognition:** Limited evidence of innovation in this area.
- **Middleware & compositional approaches:** Limited evidence of innovation in this area.
- **System architecture:** More about getting the job done for the pilot studies than going beyond the state of art.
- **Smart grid:** Clear evidence of service demand / provision models that can be linked to the smart grid.

4.28 eSESH

4.28.1 Abstract

The eSHESH project [ese] started in 2010 with the objective to design, develop and pilot (at 10 sites in 6 countries) new solutions to enable sustained reductions in energy

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency	Intelligent meters					Addressed
Scalability					Addressed	
Privacy						
Costs						
User comfort	Intelligent meters					
Adaptability						
System reliability						
Data security	SANET	SANET		SANET		
Dynamicity						
Standard Compliance						

Table 4.27: Dehems relations

consumption in social housing. The approach is to provide Energy Awareness Services (EAS) to provide direct feedback on energy consumption and Energy Management Services (EMS), which help reduce consumption peaks and optimize the timing of domestic consumption. Optimized timing of consumption can reduce generation capacity requirements and, with appropriate tariffs, tenant costs. EMS are also used to control delivery of locally generated, renewables-based heat and power.

4.28.2 Goals

The goals of eSESH is to substantially reduce peak and overall demand for energy across EU social housing, the project will develop innovative energy awareness and management services EAS and EMS. A variety of different user groups will be addressed, each with a different service proposition that must run via an appropriate energy service platform. These include homes with limited internet access; groups of older people, migrants and low income families. The goal of the service architecture is to support timely metering feedback and recommendations (including water, gas and electricity); load shedding; equipment programming and timing; landlord control of collective heating system. All of these features will be controlled via an internet portal.

4.28.3 Approach

The approach of the project is very user driven via the pilots that are conducted over the 6 countries. Each of the pilots is based on a smart meter interface to a social housing complex with sensors and actuators installed to support the feedback and recommender solutions required per user group.

4.28.4 Outcomes

The outcome of the project is a suite of energy management and energy awareness services that can be linked to (collective) smart meters and are tailored to specific user groups or to specific countries.

4.28.5 Relation to GREENERBUILDINGS

As with Dehems, the focus on residential energy management means that many of the challenges and technical solutions around energy saving are significantly different to those of GREENERBUILDINGS.

- **Building automation & operational services:** Mainly linked to user interfaces with services tailored around these, with limited use of actuators.
- **Sensors & wireless technology:** More about using existing WSAN technologies than innovating.
- **Context & activity recognition:** Limited evidence of innovation in this area.
- **Middleware & compositional approaches:** Limited evidence of innovation in this area.
- **System architecture:** More about getting the job done for the pilot studies than going beyond the state of art.
- **Smart grid:** Clear evidence of service demand / provision models that can be linked to the smart grid

4.29 HosPilot

4.29.1 Abstract

HosPilot [Hos] is a project started in 2009 that addresses the environmental aspects of hospitals. In the complex environment of a hospital, Heating, Ventilating, Air-conditioning

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency	Addressed					Addressed
Scalability					Addressed	
Privacy						
Costs						
User comfort	Addressed					
Adaptability						
System reliability						
Data security	Addressed	Addressed		Addressed		
Dynamicity						
Standard Compliance						

Table 4.28: eSesh relations

(HVAC) and Lighting account for nearly 80 percent of all energy use. The potential savings achievable with investments with a payback time of less than seven years can reach 40 percent, HVAC and lighting being the major contributors. Half of it, being 20 percent, can be attributed to the impact of ICT. The HosPilot proposed service will tailor, aims to install and tune an ICT based system that will significantly reduce the energy consumption regarding lighting and HVAC in a hospital environment. Three pilots will be executed in hospitals (in The Netherlands, Spain and Finland) during normal operation.

4.29.2 Goals

The HosPilot project will support the decision makers with an ICT based service that will drastically reduce the energy consumption of newly built hospitals and existing hospitals being refurbished, increasing well being and comfort. Three pilots will be executed in hospitals during normal operation. HosPilot will provide the most advanced ICT technology for future replications at European level.

The proposed service offers a holistic solution that provides

- advice on how to reduce energy consumption,
- the installation of the system accordingly, and
- the monitoring and tuning of energy the consumption.

The proposed service will tailor, install and tune an ICT based system that will significantly reduce the energy consumption regarding lighting and HVAC in a hospital environment. The tailoring will take into account the building, its surroundings and its usage. This service will be disseminated to the open market, so the total service can be exploited as one package by the consortium and/or other organizations, e.g. SMEs, consultancy agencies specialized in energy efficiency.

The user (hospital) can address one expert to get advice for the complete solution, instead of contacting a number of experts for the various technologies. The user will get one integrated system and service, instead of separate systems for lighting and HVAC. The service is built up of the following sub-services, which can be provided separately:

- Perform a scan in the hospital to identify the energy saving potential, including aspects such as: the climate of the environment (seasons, temperature, wind, etc); influence of daylight; building envelope (used materials, insulation, etc); operating conditions per room (24/7 usage, presence of people, required working conditions (light, air, etc).

- Provide the hospital with an ICT based blue-print to reduce the energy consumption. Computer simulations will be performed to generate this blue-print

- Tuning of energy consumption by monitoring

4.29.3 Approach

The main technology areas contributing to energy saving are lighting and HVAC. In their respective areas the following technologies, which have already been proven viable, can be used. For lighting, energy efficient light sources, mainly FL and CFL and where applicable even more efficient LED technology. Energy efficient luminaires with high performance and dimmable HF ballasts (HF-R or HF-D); smart control systems to support dimming and daylight regulation, presence detection and the use of timers

For HVAC, smart control of heating, cooling and humidification (depending on user requirements and operating hours), heat recovery from the ventilated air, heating and ventilation to daytime and night-time requirements, temperature and humidity sensors and regulators

The orchestration of the building blocks to optimize energy savings in a hospital environment will require a detailed understanding of the compromises that can be made with respect to minimal energy use and the requirements for quality, safety and comfort in the hospital. This integration will be an essential effort in the project.

4.29.4 Outcomes

The main outcome of the project is to provide an intelligent control system that will manage the overall system performance, taking into account insuring safety and quality of energy efficient resources for functional medical operation along with energy saving without compromising the patients comfort and the staffs ability to do the job. Also saving energy where and when it is not necessary to accommodate visitors. In such a complex environment, HVAC and Lighting account for nearly 80 percent of all energy use. The potential savings achievable of such a system with investments with a payback time of less than seven years is expected to reach 40 percent, HVAC and lighting being the major contributors. Half of it, being 20 percent, can be attributed to the impact of ICT.

The project will take into account different zones and their associated activities within the hospital building, including: corridors and other traffic areas (turn down ventilation at night, dim lighting etc,); waiting areas (occupancy sensitive and out-of-hours); patient/nursing wards; polyclinic (task based lighting); operating theaters and intensive care; labs; admin departments and hospital surroundings. The figure below shows how, in a first step, the energy usage per segment decreases after refurbishment. By adding intelligence to the system using ICT, energy use can be significantly reduced further in a second step.

4.29.5 Relation to GreenerBuildings

There are several aspects of HosPilot that coincide with GreenerBuildings. Firstly the environmental sensing aspects of the hospital setting with respect to energy efficiency and building automation are considered key aspects of the service architecture. Also the compositional approach over HVAC and Lighting systems and decision support is likely to have some similarities. It is not clear from the project description what kind of middleware and context sensing technology will be used. However, the decomposition of the building into zones that are linked to user tasks and behaviors is clearly related.

- **Building automation & operational services:** Environmental sensing aspects of the hospital setting with respect to energy efficiency and novel forms of building automation are considered key aspects of the service architecture.
- **Sensors & wireless technology:** Evidence of the use of wireless sensor technologies, but it is not clear if this goes beyond the state of the art.
- **Context & activity recognition:** It is not clear from the project description what kind of middleware and context sensing technology will be used.
- **Middleware & compositional approaches:** It is not clear from the project description what kind of middleware and context sensing technology will be used.

- **System architecture:** The architecture is oriented around different zones and the activities related to those zones within hospital. In this sense, there are likely to be similarities in the run-time system architecture.
- **Smart grid:** Not clear how this links to the smart grid.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency	Smart HVAC control				Efficient light, smart HVAC control	
Scalability					Addressed	
Privacy						
Costs						
User comfort	Smart HVAC control					
Adaptability						
System reliability						
Data security						
Dynamicity						
Standard Compliance						

Table 4.29: HosPilot relations

4.30 Sensei

4.30.1 Abstract

SENSEI (Integrating the Physical with the Digital World of the Network of the Future [SEN]) is an FP7 IP project that started in the beginning of 2008 with 19 partners. The aim of the project is to create a global and pluggable framework for wireless sensor and actuator networks.

- Integrating the Physical with the Digital World of the Network of the Future.
- SENSEI creates an open, business driven architecture that fundamentally addresses the scalability problems for a large number of globally distributed WSandA devices.

It provides necessary network and information management services to enable reliable and accurate context information retrieval and interaction with the physical environment. By adding mechanisms for accounting, security, privacy and trust it enables an open and secure market space for context awareness and real world interaction.

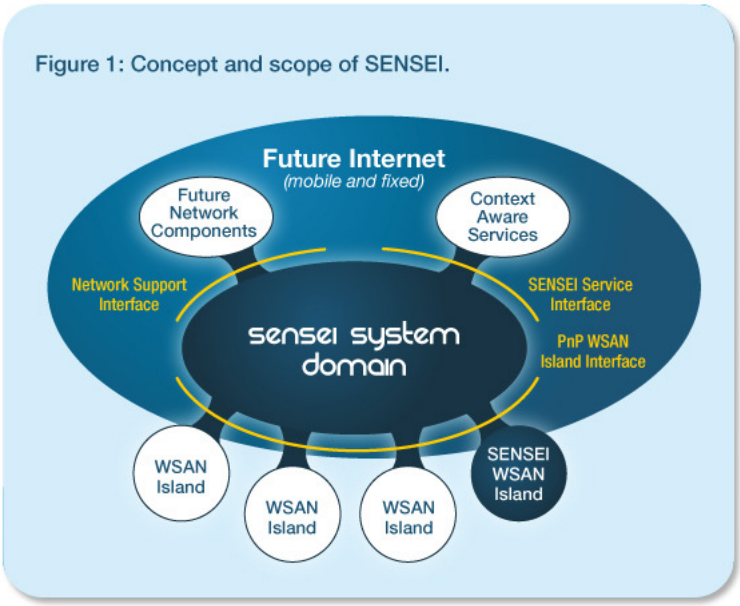
- Distributed Activity Recognition, Service Discovery and Composition in Body Area Networks, Activity Recognition in Service Oriented Body Area Networks

4.30.2 Goals

In order to realize the vision of Ambient Intelligence in a future network and service environment, heterogeneous wireless sensor and actuator networks (WSandAN) have to be integrated into a common framework of global scale and made available to services and applications via universal service interfaces. SENSEI creates an open, business driven architecture that fundamentally addresses the scalability problems for a large number of globally distributed WSandA devices. It provides necessary network and information management services to enable reliable and accurate context information retrieval and interaction with the physical environment. By adding mechanisms for accounting, security, privacy and trust it enables an open and secure market space for context-awareness and real world interaction.

4.30.3 Approach

As shown in the figure below, the approach of the project is to develop interfaces to future network components, context aware services and wireless sensor network environments and to evaluate it effectiveness (e.g. scalability, performance) through large scale trials, which are driven by selected business cases and scenarios. The work is split into three main activities: development of a framework to support global and pluggable sensor and actuator networks; provide sensor information services and develop efficient wireless sensor and actuator systems.



4.30.4 Outcomes

Tangible results of the SENSEI project are: 1) A highly scalable architectural framework with corresponding protocol solutions that enable easy plug and play integration of a large number of globally distributed WS and AN into a global system providing support for network and information management, security, privacy and trust and accounting. 2) An open service interface and corresponding semantic specification to unify the access to context information and actuation services offered by the system for services and applications. 3) Efficient WSAN island solutions consisting of a set of cross-optimized and energy aware protocol stacks including an ultra low power multi-mode transceiver targeting 5nJ/bit. 4) Pan European test platform, enabling large scale experimental evaluation of the SENSEI results and execution of field trials - providing a tool for long term evaluation of WSAN integration into the Future Internet.

4.30.5 Relation to GREENERBUILDINGS

The architecture for PnP wireless sensor and actuator networks is likely to play an important role along with the ability to link in context aware services.

- **Building automation & operational services:** Not specific to this field, but it is possible that there are scenarios developed within the initiate that link to it.
- **Sensors & wireless technology:** There are many aspects where WSAN technologies and services that are relevant for WSAN related requirements of GREENERBUILDINGS

- **Context & activity recognition:** The framework can support it, but the initiative does no innovate in this area.
- **Middleware & compositional approaches:** High degree of relevancy
- **System architecture:** The architecture is not tailored to the scope and requirements of GREENERBUILDINGS

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency						
Scalability		WSandA			WSandA	
Privacy						
Costs						
User comfort						
Adaptability						
System reliability				Network & information management services		
Data security						
Dynamicity						
Standard Compliance			PNP	Future network components	Future network components	

Table 4.30: SENSEI relations

4.31 3e-Houses

4.31.1 Abstract

3e-HOUSES [eH] project deals with the integration of the most established ICT technologies in social housing in order to provide an innovative service for energy efficiency:

- Real time monitoring of the energy consumption
- Integration of renewable energies
- Creating the resources to lower energy consumption

4.31.2 Goals

Allow tenants to develop or enhance their relationship with the utility, the environment, as the concept, saving energy is saving CO2 emissions. Allow the integration of renewable energy and other sources of distributed energies.

4.31.3 Approach

The goals of the project are expected to be achieved by piloting in several social housing buildings the interaction between smart devices and the users to create, in a first approach, awareness around their energy consumption and therefore a change in their energy-use patterns.

4.31.4 Outcomes

The expected outcomes of the project are four demonstration pilots:

- Pilot 1: Spain. Three social houses in Sant Cugat del Valls, Spain, divided into two constructions containing 64 and 56 flats respectively. The maximum number of houses is expected to be 80.
- Pilot 2: Germany. Social house in Leipzig (Germany) containing 33 flats.
- Replication 1: Bristol. 100 Social Housing Units in Bristol, made up of approximately 60 flats within a housing block and 40 houses dispersed through an area of social housing.
- Replication 2: Bulgaria. Social house promoted by BHA in Sofia (Bulgaria) containing 44 flats.

4.31.5 Relation to GREENERBUILDINGS

The 3e-HOUSES project has identified the need to develop two categories of methodologies, to measure the extent of achievement of the expected results, and to perform the analysis of results and impacts of the project, namely:

- Methodology for Energy Efficiency Measurement
- Methodology for Impact Assessment

GREENERBUILDINGS can take advantage of those methodologies for their application to the Context and Activity recognition field.

- **Building automation & operational services:** The platform considers the possibility of performing Demand Side Management.
- **Sensors & wireless technology:** Metering and sub-metering of energy use through low-power commercial wireless solutions.
- **Context & activity recognition:** Context-awareness is indirectly considered, as the energy use monitoring methodology considers different options or user profiles.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency		Renewable energies, consumption monitoring				
Scalability						
Privacy						
Costs		802.15.4				
User comfort						
Adaptability						
System reliability						
Data security						
Dynamicity						
Standard Compliance		802.15.4				

Table 4.31: 3e-Houses relations

4.32 Be Aware

4.32.1 Abstract

BeAware [BeA] aims to develop services for conserving electricity within households. The goal of these services is to reduce power consumption within households by 15%. The project builds a service platform that will ensure scalable, deployable innovation in the consumer power market, enabling a combined service to monitor the consumption and understand the effects of different choices. This can create opportunities for learning better practices or incentives for adopting virtuous behaviors.

4.32.2 Goals

The prime challenge in BeAware is to provide the consumer with a new kind of feedback about electricity conservation and turn them into active and responsible consumers. It will integrate awareness cues through mobile and ambient interfaces into consumers' everyday lives taking into account cognitive capabilities and social practices. This will enable to:

- Monitor the consumption and understand the effects of different choices.
- Control with more precision power consuming appliances and systems (lights, heating, etc.) with advanced personalization.
- Share consumption practices in groups and communities. This can create opportunities for learning better practices or incentives for adopting virtuous behaviors

4.32.3 Approach

The technology developed in the project will be set up in two different pilot sites; one Nordic field site (Sweden/Finland) and one Southern European field site (Italy). In each site, studies will be carried in a home environment. The research approach is highly multidisciplinary and combines a variety of approaches in the area of user studies, user centered design and evaluation. Disciplines include cognitive science, social psychology, anthropology, and design. The user research approach will be a combination of qualitative and quantitative field studies and trials.

4.32.4 Outcomes

The main project outcome is Energy Life, a game which gives the users feedback on how effective their use of energy is at home. Such feedback can be conveyed to the user by mobile or ambient interfaces. Energy Life also raises awareness on the power energy consumption through smart tips and quizzes. The rationale for the Energy Life concept is that game inspired applications can contribute to turn energy consumers into active ones, and engaging them to share their energy-saving behaviors within their community. This is enabled by social network technologies, and empowers them to adopt energy conservation practices. At the core of BeAware there are user-friendly technologies and concepts, driven by innovative cognitive models and social studies on the behavior of the energy users.

4.32.5 Relation to GREENERBUILDINGS

GREENERBUILDINGS can mainly make use of the Service Layer Architecture defined within the BeAware project as shown in

- **Building automation & operational services:** Service platform for monitoring energy use in order to build models and improve consumer practices.
- **Sensors & wireless technology:** The sensing network installed to household consists of:
  - low power base station for gathering sensor data and handling communication to platform
  - plug-in wireless sensors collecting high resolution information on energy consumption and power quality.
  - wireless sensors for reading house main meter for overall consumption The wireless network operates over 433 MHz band, offering better range and lower consumption than normally used ZigBee-based solutions. Data is analyzed at 1 kHz frequency and communicated to base station at 1/2 Hz frequency. Compared to normal solutions this allows the system to analyze the states and types of devices connection.
- **Middleware & compositional approaches:** A base station inside the house collects information from the different devices, and through specific interfaces is able to publish than information for users awareness. The middleware handles all the monitoring services, for capturing events and energy usage information.
- **System architecture:** The system is based on a wireless sensor network, energy meters, communication infrastructure, data storage and third party sensor devices.

4.33 IntUBE

4.33.1 Abstract

IntUBE [Int] will develop tools for measuring and analyzing building energy profiles based on user comfort needs. These will offer efficient solutions for better use and management of energy use within buildings over their life cycles. Intelligent Building Management Systems will be developed to enable real-time monitoring of energy use and optimization. Neighborhood Management Systems will be developed to support efficient energy distribution across groups of buildings. These will support timely and optimal energy transfers from building to building based on user needs and requirements. New Business Models to make best use of the developed Management Systems will be created. The results of IntUBE are expected to enhance not only the comfort levels of buildings users, but also reduce overall energy costs through better energy efficiency. These results will be demonstrated in at least three pilot cases: social housing in Spain, office buildings in Finland and a third case defined during the project.

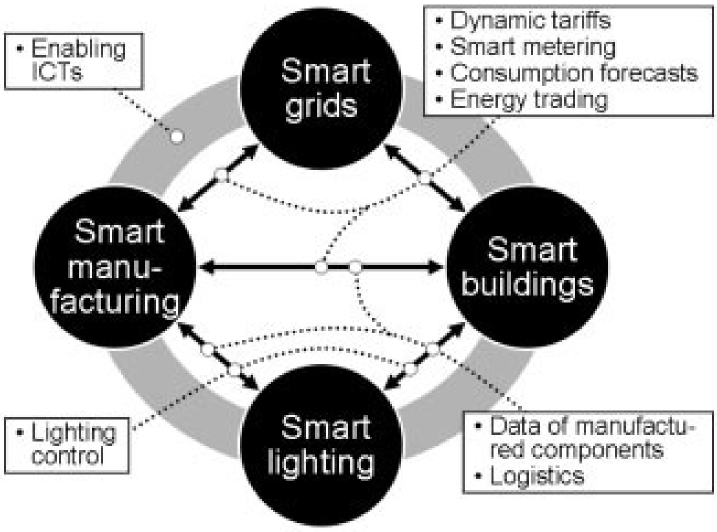


Figure 4.7: The Service Layer Architecture

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency		433 MHZ proprietary			Energy usage monitoring	
Scalability						
Privacy						
Costs						
User comfort						
Adaptability						
System reliability						
Data security					433 MHZ proprietary	
Dynamicity						
Standard Compliance		433 MHZ proprietary				

Table 4.32: BeAware relations

4.33.2 Goals

IntUBE will lead to increased life-cycle energy efficiency of the buildings without compromising the comfort or performance of the buildings by integrating the latest de-

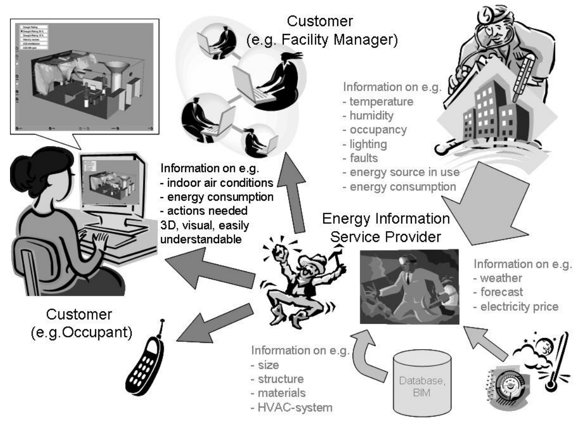


Figure 4.8: IntUBE objectives

velopments in ICT-field into Intelligent Building and Neighborhood Management Systems (IBMS and NMS) and by presenting new ICT-enabled business models for energy-information related service provision.

One aim is to use the available information like performance, size, use, material, energy consumption and renovation actions in an efficient way. That could contribute a considerable improvement of energy efficiency also for new buildings. (It is estimated that 20% energy savings can be achieved by using BMS alone) Therefore the information needs to be collected and handled in an intelligent way. The actors like the owners, the users, the energy service providers, maintenance service providers, etc could get exactly the information they need in a format that would be most useful to them to interfere in the energy issues only when actions are imperative.The improvement will be further increased by the use of intelligent and interactive user interfaces that increase the consciousness of energy issues, support the end user to make the right choices from energy efficiency point of view and by the efficient management of local heat and power networks.

4.33.3 Approach

An open platform developed in IntUBE will enable to integrate these technologies into IBMS and NMS. Some development may also be needed in individual technologies to enable the integration. This may include e.g. integration of the mobile phones as user interfaces or meter readers into Building Management Systems (e.g. with NFC-technology). In order to cover the whole lifecycle, the IBMS and NMS must also include simulation tools to enable energy profiling of the buildings and neighborhoods. The Local Planning Tool developed in IntUBE will provide information to decision makers already in the early phases of design. Neighborhood management includes the management of local heat and electricity networks to enable the efficient integration of renewable energy sources to the distributed energy systems.

4.33.4 Outcomes

The effect of the new IBMS and NMS on the energy efficiency of buildings or local energy grids will be demonstrated in three pilot cases. After the validation of the IBMS and NMS the IntUBE neutral energy information structures will be developed from a project based standard into an international standard by suggesting changes and additions to existing international IAI IFC/IFD standard, today the most accepted open standard for construction ICT integration.

4.33.5 Relation to GREENERBUILDINGS

GREENERBUILDINGS can take advantages of the IntUBE approach regarding Neighborhood management systems. The management of distributed energy systems – where energy is produced close to where it is being used – needs new types of analysis tools to design and to optimize energy chains extending from generation sites (both large and small scale) to consumption points. IntUBE investigates the distributed energy generation concept and in particular its potential application to heating networks. The objective is to develop a new tool to simulate local generation within district energy networks and to elaborate new concepts regarding the potential of dynamic smart energy metering. IntUBE investigates innovative ICT solutions for energy efficiency both at building (BMS) and district (NMS) levels. The energy meter is precisely the device that establishes the interface between a building and energy networks. Therefore, as a matter of course IntUBE concentrates particular attention to the new range of smart and dynamic energy meters offering new abilities and allowing a wide range of new services. The BIM data structure will be based on existing international open standard IFC (Industry Foundation Classes) from the IAI/BuildingSmart initiative. For energy-related aspects this schema has to be dynamically extended (externally defined semantics controlling the needed extra proxies and property sets). Candidate technologies are SWOP PMO, IFD, or both.

- **Building automation & operational services:** IntUBE defines an innovative service platform where Building Information Model is used as basic data structure. The IntUBE service platform can be seen as the integrating common software infrastructure for relevant software applications (CAD, energy calculation/simulation, monitoring, controlling, etc.) and/or services. Via this service platform, various (multi-vendor) applications can exchange (transfer and/or share) energy-related building information (static and dynamic) having been defined according to agreed open standards.
- **Middleware & compositional approaches:** Besides openness (or ‘interoperability’), smartness (or ‘semantics’) is the key aspect: the ICT applications will communicate via this platform on the basis of semantic building objects, their properties and their relationships which are relevant to the energy management view in the operational phase of (existing) buildings and their energy-related installations.

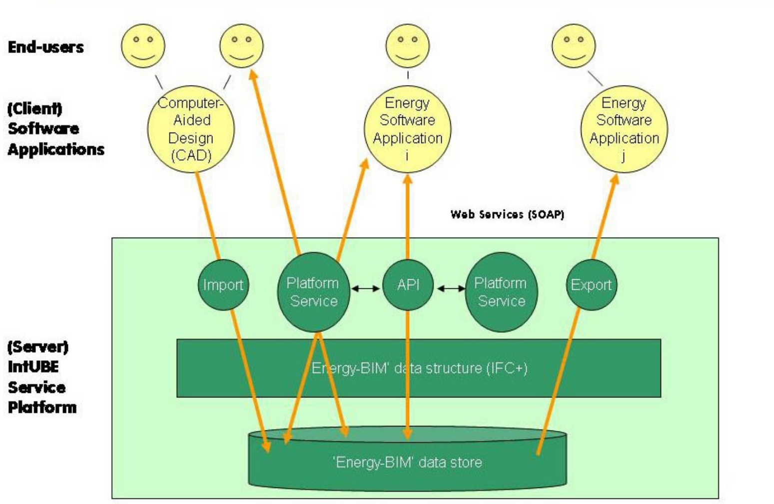


Figure 4.9: IntUBE Service Platform

IntUBE will provide new concepts of services taking advantage of smart meters' dynamic information. Data access is realized via import/export and/or application programming interfaces or higher-level common (web) services on top of them.

- **System architecture:**System architecture is largely distributed over a two layer structure (at least) that is the basis realizes intelligent and interactive monitoring of energy utilization, production, distribution, storage, use and possibly trading. These targets are achieved through a local or a network of cooperative local embedded controllers.

4.34 SportE2

4.34.1 Abstract

The aim of SPORTE2 [Spo] is to develop an integrated, modular, and scalable ICT system to manage energy consumption, generation, and exchange locally and within the larger context of the smart grid/neighborhood, focused in sports and recreational buildings.

4.34.2 Goals

1. Develop a building management system based on smart metering, integrated control, optimal decision making, and multi-facility management.

2. Reduce energy consumption up to 30%

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency		Dynamic smart energy metering				NMS
Scalability				IBMS		
Privacy				IBMS		
Costs						
User comfort						
Adaptability						
System reliability				IBMS		
Data security						
Dynamicity		Dynamic smart energy metering				
Standard Compliance						

Table 4.33: IntUBE relations

3. Enable a new relationship and business model structure between facility managers and power providers

4.34.3 Approach

The project will make use of a full scale building laboratory environment (Kubik) for system integration and testing. The project will then implement the SPORTE2 modules in three full-scale pilots representative of the sector (e.g. swimming pools, indoor and outdoor courts, gyms, etc) and able to implement the smart grid concept through the availability of RET and cogeneration devices. Strong linkages to sport associations and green building design are present in the consortium to enable exploitation of project results.

4.34.4 Outcomes

SPORTE2 aims to manage and optimize the triple dimensions of energy flows (generation, grid exchange, and consumption) in Sport and Recreation Buildings by developing a new scalable and modular BMS based on smart metering, integrated control, optimal decision making, and multi-facility management. This tool will enable a new relationship and business model structure between facility managers and power providers.

The SPORTE2 modules will be applicable to both new and existing structures and answer the fundamental questions of how, where, when and why energy is produced, used and grid exchanged. The approach will target a reduction of energy consumption, with commensurate CO2 reductions and cost savings.

4.34.5 Relation to GreenerBuildings

GreenerBuildings can make use of the demonstration-oriented approach followed by SPORTE2, in order to assess energy efficiency, scalability, costs, system reliability and adaptability of the whole solution applied in a real scenario.

This is a new project that it is just starting, therefore there is not much details available.

- **Smart Grids:** The project aims to develop technology to perform energy exchange locally and within the larger context of the smart grid/neighborhood.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency						BMS, Smart metering
Scalability						
Privacy						
Costs						
User comfort						
Adaptability						Grid exchange
System reliability						
Data security						
Dynamicity						
Standard Compliance						

Table 4.34: SportE2 relations

4.35 TIBUCON

4.35.1 Abstract

The aim of the TIBUCON [TIB] project is to develop Self Powered Multi Magnitude Wireless Sensor Network technology (SP-MM-WSN) that will be used in building thermal condition monitoring for either new or existing HVAC installations. SP-MM-WSN along with an actuating scheme will allow optimized real time control, or at least automatic monitoring and user energy awareness for the retrofit cases. The project will result in a more cost effective and less invasive tool for HVAC retrofitting and more efficient HVAC structure in terms of energy consumption and thermal comfort for new installations. Both alternatives will have an important impact on the energy consumption and CO2 emission of the HVAC systems, and due to the wire and battery reduction, the use of limited resources (cooper, PVC, heavy metals, etc) and waste generation (batteries disposal) will be reduced.

4.35.2 Goals

The aim of the project is to achieve a reduction of the energy consumption through HVAC system performance enhancement thanks to the ICT based building integral wireless connectivity system that will support the building thermal condition monitoring and real time control and actuating scheme. The project will address the following scientific and technological objectives:

1. Empower old and new building monitoring through extremely cost effective SP-MM-WSN through the integration of a low power wireless communication protocol within the building integral communication architecture and development of hybrid indoor energy harvesting units for powering self powered wireless sensors

2. Development of thermal simulations of the heating system and the continuous comparison with the data from the sensors.

3. Demonstrate the TIBUCON system through one year period on two pilot test-beds: new office building and existing apartment blocks.

4.35.3 Approach

TIBUCON project is intended for old and new buildings. Thus, two application scenarios are being considered to exploit the proposed solution:

1. New Installation: For new buildings with a new HVAC installation, the use of smart actuators with wireless connection and remote control capabilities will allow auto-

matic actuation. In this scenario the HVAC can be controlled in real time, resulting in a more efficient and transparent system.

2. Retrofitted Installations: Taking into account that old buildings (¡1975) are responsible for 70 percent of total energy consumption for heating , there is a huge energy saving potential in that sector; moreover, if the current rates of construction of new buildings (below 2 percent) and building destruction rates (even lower at circa 0.5 percent) are considered. The usual refurbishment actions in old buildings involve typically better insulations, boiler and piping changes, etc. but the heating and cooling control systems usually remain the same.

4.35.4 Outcomes

Both scenarios will be demonstrated during the project execution:

- New building with new HVAC system to be installed with TIBUCON solution for obtaining improved efficiency. Multi-tenant Office building in Poland has been selected for this point.

- Existing building with old HVAC installation to be refurbished with the help of the solution proposed in TIBUCON project. A group of apartment buildings in the north part of Spain has been considered for this demonstration.

4.35.5 Relation to GREENERBUILDINGS

GREENERBUILDINGS can take the advantages of this project to evaluate and test the results.

- **Building automation & operational services:** The project aims to control HVAC equipments in buildings.

- **Sensors & wireless technology:** Low power wireless communication protocol within the building integral communication architecture and development of hybrid indoor energy harvesting units for powering self powered wireless sensors

- **Middleware & compositional approaches:**

- **System architecture:** Low cost sensors for controlling HVAC and Hybrid Power Harvesting Unit (photovoltaic, thermoelectric, vibration energy) to power sensors.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency	HVAC control	SP-MM-WSN				
Scalability		SP-MM-WSN				
Privacy						
Costs		SP-MM-WSN			SP-MM-WSN	
User comfort						
Adaptability						
System reliability						
Data security						
Dynamicity						
Standard Compliance						

Table 4.35: TIBUCON relations

4.36 Pebble

4.36.1 Abstract

In the design and operation of positive-energy buildings a pragmatic target is maximization of the actual net energy produced (NEP) by intelligently shaping demand to perform generation-consumption matching. To achieve this, informed decisions in (almost) real-time are required to operate building subsystems and to account for unpredictable user-behavior and changing weather conditions. With the belief that maximization of the NEP for Positive-Energy Buildings is attained thru Better ControL dEcisions (PEBBLE [PEB]), a control and optimization ICT methodology that combines model-based predictive control and cognitive-based adaptive optimization is proposed. The project is about utilizing harmoniously, and most effectively all installed systems in a building, taking into account human factors and adapting the decisions in (almost) real-time as and when uncertainties occur.

4.36.2 Goals

PEBBLE's [PEB] main objective is to develop, implement in real-life buildings and evaluate a fully-functional EPB real-time optimization and control system by:

- Advance methodology and designs and technology in order to appropriately and efficiently address and integrate the aforementioned three components,
- Integrate the proposed designs in the aim of providing efficient, robust and rapidly-adapting real-time Building Optimization and Control (BOandC) for EPBs of arbitrary scale and complexity, location and design methodologies while
- Employing sensor, user-interfaces and control devices technologies that are easy-to-deploy and, most importantly, are cost-efficient.

4.36.3 Approach

The building is perceived as a dynamical system comprising the various subsystems and building occupants. This last part is especially important as occupant actions (e.g. opening and closing windows) and activities (e.g. sedentary work) directly influence the thermal behavior of the building and the type of decisions that must be taken. The building responds with respect to external (weather) and internal (user) excitations, according to dynamics prescribed by the building construction, with controllable elements that operate according to the decisions taken by the PEBBLE system. There are three essential elements to the PEBBLE system:

- The first is accurate and efficient simulation models for EPBs that incorporate all passive, active and energy-generation elements and, given local weather data and weather prediction models, can be used to predict thermal response, energy requirements, and estimate user comfort. These predictive building models incorporate physical modeling and depart from more traditional and less reliable data-driven approaches.
- The second is sensors, actuators and interfaces that are used to facilitate communication and information exchange from the physical to the simulation layers.
- The third element is efficient and robust Building Optimization and Control (BOandC) tools that use sensor inputs and the thermal models to evaluate potential scenarios, and take (almost) in real-time decisions for the operation of the building subsystems with the goal of maximization of the NEP and retaining building conditions at user-acceptable comfort levels.

Building occupants have a dual sensor-actuator role in the PEBBLE framework: through user-interfaces humans act as sensors communicating their thermal comfort preferences to the PEBBLE system, and in return the PEBBLE system returns information with the goal of educating and enhancing energy-awareness of the users, engaging them in the effort of taking proper decisions.

4.36.4 Outcomes

- Thermal simulation models: accurate representations of the building and its subsystems
- Sensors, actuators, and user interfaces to facilitate communication between the physical and simulation layers
- Generic control and optimization tools that use the sensor inputs and the thermal models to take intelligent decisions

4.36.5 Relation to GREENERBUILDINGS

Pebble project is relevant to various extents to the GREENERBUILDINGS project. Particularly, its model-based predictive control and cognitive-based adaptive optimization will be studied as baseline for upcoming tasks.

- **Sensors & wireless technology:** The system will make use of Smart Metering, but it is not clear what specific type of technology is going to be used regarding the sensors and the communications infrastructure.
- **Context & activity recognition:** The platform interacts with the building and it occupants, thus introducing the concept of context awareness. This awareness takes the form of outputs from the monitoring system that is sent back to the users to have feedback on their behaviors.
- **System architecture:** The architecture considers a building (renewable sources, passive systems, HVAC systems, and users) that interact with control-decision and optimization tools through an adequate networking/communications infrastructure.

4.37 HOMES

4.37.1 Abstract

The HOMES (Homes and buildings Optimized for Mastery of Energy and Services) was motivated by the fact that in Europe, buildings account for nearly 40 percents of total energy consumption and 25 percents of total CO2 emissions. Stakeholders involved in the building sector are gradually becoming aware of the new imperatives to improve energy consumption management in buildings, irrespective of their motivation. Owners wish to reduce the environmental footprint of their buildings and thus identify the most efficient improvements for their buildings. Site managers wish to identify consumption, wastage and potential energy savings while improving site comfort and productivity. Maintenance

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency		Sensors, actuators & interfaces				
Scalability						
Privacy						
Costs						
User comfort					BOandC, simulations	
Adaptability			Preferences through user interfaces			
System reliability						
Data security						
Dynamicity						
Standard Compliance						

Table 4.36: PEBBLE relations.

technicians need to adapt the operation of the machinery to the buildings flexibility of use (change of occupants, tenants, use, purpose etc.) and also detect and analyse operational drifts. Finally, occupants wish to be able to adapt their environmental conditions and to make them ideal for their activity, pertained to lighting and thermal comfort, air quality etc.

The HOMES project was supported by national collaborative innovation program, funded by OSEO. The duration of HOMES was 4 years, from 2008-2012. The project had the generic ambition to equip each building with solutions to achieve the best energy performance. The projects idea was to create new control architectures for buildings optimized energy management through optimized use of equipment and energy, measurement, monitoring and continuous improvement of the performance level and cooperation between partners.

4.37.2 Goals

The goals of the HOMES project are related to reduction of the energy needs and CO2 emissions through active energy efficiency. The principle of active energy efficiency focuses on people and how they use the building, equipment and energy. The need is therefore to:

- Reduce energy demand in each room and maintain optimum conditions of comfort and activity by taking into account real time occupancy and free inputs such as solar gains through windows.
- Optimized delivered energy through new strategies for optimized equipment control and use of local renewable energies and smart grid connections.
- Maintain performance during the buildings life cycle thanks to energy metering and consumption monitoring.
- Provide relevant information in order to get people involved by developing energy awareness.

The main goal of the HOMES project was to provide higher energy efficiency for all buildings while maintaining or improving comfort.

4.37.3 Approach

The HOMES project had three phases. In the first phase, the regulatory and label calculations regarding evaluation of the energetic standards have been done. This included recognition of the needs, conventional usage, conventional climate conditions and identifying building and equipment types.

The second phase represented simulations of the real sites and the objective was to evaluate potential energy savings provided by HOMES energy efficiency solutions. The simulation of the real site included usage of the building model, energetic audit, discussions with the occupants, measurements and expertise. There were two simulations per site:

1. The real-life operations (including manual behaviour) before HOMES.
2. The automatic operations by applying the HOMES control strategy.

The third phase represented performance of measurements on the real site. These measurements have included consumptions, identification of the real usage, real climate conditions and building equipment and also have incorporated real faults in realization, in regulation of the devices, faults in functioning as well as actual behavior of occupants.

The HOMES project has designed simulation models to be applied to five pilot sites, on which it has collected measurement data and conducted simulation test of active control functions. The five chosen buildings are deemed to be representative. A variety of buildings are involved (offices, hotels, schools and residential buildings), new or existing, possibly refurbished, covering a surface area between 500 and 3000m^2. The main projects approaches are listed in the table below.

homes	APPROACH	OBSERVATION	ACTION
1	Take into account the real occupancy of each zone in the building	In many cases, unoccupied areas of the building are provided by the same level of comfort as occupied areas.	Provide optimal comfort where and when is needed and save energy in all other cases.
2	Adapt the level of comfort to the occupants, their activity and their preferences	Required temperature and lighting levels vary greatly according to the type of activity and the metabolism, age and clothing of each occupant.	Manual and/or automatic adjustment of the levels to the real need, either room by room or for each workstation, makes it possible to increase occupant satisfaction and reduce misadjustments made by unsatisfied occupants.
3	Use free inputs	A great deal of free heat and light can be obtained through the windows. The air outside the building can be used for heating or cooling.	Control blinds and shutters to let solar radiation enter in winter and keep it out in summer. Use illumination level detectors and anti-glare systems to allow maximum use of natural light. Use free cooling whenever possible.
4	Optimize by using multi-application control	A building is a complex system in which energies and applications interact. To achieve optimum energy performance, the overall system must be taken into account.	Use sensors and advanced algorithms to choose the best options taking into account the performance of the building envelope, the equipment, energy costs and comfort and activity needs. Use solutions based on application interactions and coordination.
5	Improve the performance of HVAC equipment at production, distribution and emission levels	Even quality equipment will lose performance if it is not used correctly. Equipment is often not properly adjusted.	The temperature of the heating or cooling liquid must be properly adjusted. Control systems can be used to maximize continuous operation or ensure the best compromise with respect to start/stop requirements. Advance control techniques can be used to make thermodynamic systems operate more efficiently.
6	Manage energy sources with priority to on-site renewable energy while satisfying network constraints (Smart Grids)	Energy procurement is rapidly changing.	Connect to different energy sources and storage systems. Communicate with energy providers . Determine the best strategy for energy input (buy, store or sell). Determine the best strategy for loads (anticipate or delay starting, shed etc.).
7	Create energy awareness	Our everyday behaviour is often hungry.	Use inexpensive measurement equipment that is easy to install and to obtain sufficiently detailed energy consumption information. Use indicators that are easy to understand and motivating, adapted to each profile. Use tools to convince building owners. Provide simulation tools to building professionals.

Figure 4.10: HOMES' main approaches.

4.37.4 Outcomes

The outcomes of the project are:

1. Implementation of the multi-application control solutions in each zone which provides a great flexibility in the case of a change of occupants, tenants, usage of rooms, purpose etc.

2. Designing of Human-Building Interface solutions for occupants, managers, facility managers and owners. They used Human-Building interfaces to make energy data more easily accessible and understandable, while allowing human operators a degree of autonomy and decision-making in the building management process.

3. Developing design tools for the industry sector that can avoid data re-entry and save time, prevent data loss and improve the understanding of all those involved.

4. Estimation of gains provided by the HOMES active control functions the results of the simulation:

    - Montbonnot primary school 56% of energy consumption saved by controlling the air quality and the thermal comfort according to the real occupancy level.
    - Savoie Technolac office building 36% of savings by optimized management of lighting (switching off when employees are absent, adjusting the light level needed when they are present) and other uses of electricity (equipment set to standby at night and weekends)
    - A 3-star hotel in Nice 37% of savings by optimized management of heating according to occupancy levels and ventilation using data provided by CO2 sensors.
    - Residential building at Vaux-sur-Seine 22% of savings by optimized management of heating according to the occupancy level, ventilation according to the data from the CO2 sensors and lighting according to the requirements (this parameter is linked to opening/closing of roller blinds so as to benefit from natural light).
    - Hotel in Carcassonne 30% of savings mainly by setting to energy idle mode when the rooms are not occupied, by optimized management of heating and ventilation according to data from the CO2 sensors.

5. HOMES prototypes:

    - Comfort sensor an autonomous wireless multi-sensor (temperature, humidity, light intensity and CO2) for comfort based control based on the ZigBee standard.
    - Roombox a multi-application and decentralized control and command device.
    - EE HVAC emission a controller for optimized emission.
    - Smart energy center a solution for house connection to the Smart Grid and to local electrical sources.
    - ZigBee Smart Grid residential information system a system helping user taking actions, as a response to Smart Grid demands: load shedding, local energy consumption information.

4.37.5 Relation to GreenerBuildings

GreenerBuildings project can take advantage of the HOMES project in the following areas: domotics & building operational services, sensors & wireless technologies, context & activity recognition, middleware & compositional approaches and Smart Grid.

- **Domotics & building operational services:** The HOMES project includes connection to the existing BMS systems and exchanging of data, if applicable, through the one of the prototypes of the project the Roombox. The Roombox is used for controlling the different building systems such as HVAC, lighting, blinds, etc.

- **Sensors & wireless technology:** Different sensor modalities have been used and developed in the HOMES project. The prototypes that can be used in GB project are:

  - Comfort sensor, which represents autonomous selfpowered wireless multi-sensor which measures temperature, humidity, light intensity and CO2 levels. It uses solar cell for powering and ZigBee protocol for communication.
  - The Roombox device can also serve as gateway between wired, wireless communication protocols and for integration with existing BMS system, if needed.
  - EE HVAC emission controller for optimized emission controls fan motor with variable speed and exchange data with BMS and the Roombox by sending local zone information (temperature, thermal and electrical consumption) and receiving information about set points.

- **Context & activity recognition:** The HOMES project aimed at reduction of energy needs by taking into account comfort and activity conditions. The system adapted to occupancy, however not to other user activity. The sensors analyzed the environmental conditions (humidity, temperature, air quality, brightness, presence, external weather conditions) and sent this contextual information to HOMES controllers. The controller drives the equipment according to sensor data or instructions from occupants while consuming the least energy.

- **Middleware & compositional approaches:** Optimization by using multi-application control is one of the HOMES project approaches. Multi-application control uses sensors and advanced algorithms to choose the best option taking into account the performance of the building envelope, the equipment, energy costs and comfort and activity needs. It uses solutions based on application interactions and coordination.

- **Smart Grid:** The Smart Grid energy center is the one of the prototypes of the HOMES project. It represents a solution for connection to Smart Grid and local electrical sources. It optimizes energy supply from various vectors and manages energy sources by prioritization of renewable energies and free inputs under grid constraints. It implements the following control functions:

  - Optimization of heating and cooling medium distribution (temperature and flow).
  - Management of energy storage: water tanks, building thermal inertia, electrical batteries.

– Optimization of HVAC production.

– Smart Grid functions: peak shaving, comfort set point variation, selective load shedding.

– Optimization strategies for energy production, storage and/or buy-sell.

There is also the ZigBee Smart Grid residential information system, which helps users to take action as a response to Smart Grid demands. It allows load shedding based on tariff change or current power and it provides dynamic pricing messages on digital photo frame.

The relations of HOMES to GREENERBUILDINGS are summarized in Table 4.37.5.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency	Roombox	Occupancy sensors	Context and energy awareness	Multi-application control		Smart Energy center
Scalability						
Privacy						
Costs						
User comfort		Comfort sensor	Adapt the level of comfort to the occupants, their activity and preferences	Human-Building Interface		ZigBee Smart Grid residential system
Adaptability	Roombox			Multi-application control		
System reliability						
Data security						
Dynamicity						
Standard Compliance	BMS system	ZigBee standard, self-powered				ZigBee standard

Table 4.37: HOMES relations.

4.38 SCUBA

4.38.1 Abstract

Large scale embedded Monitoring and Control (M&C) systems in energy management, transportation, security and safety often co-exist alongside each other with little cooperation within and among heterogeneous systems, which hampers the increasing demand to operate the whole system optimally. A good example is building management, a market worth in excess of 36 billion dollars annually by 2015, where a wide range of vendor specific, heterogeneous M&C systems for HVAC, access control, fire and safety, etc. are in use. This stove pipe system approach limits optimal solutions to energy efficiency, occupant comfort, or fire safety, especially as most systems need to evolve over time and have to deal with unexpected or unpredictable dynamics, such as fire. The SCUBA project (Self-organising, Cooperative and robust Building Automation) intends to create a novel architecture, services, and engineering methodologies for robust, adaptive, self-organising, and cooperating monitoring and control systems to address the current problems of heterogeneity and interoperability, installation and commissioning complexity, and adaptability and robustness in the building monitoring and control space.

The SCUBA project is funded by the European Commission, within the Seventh Framework Programme. It started in November 2011 and has a time frame of 36 months.

4.38.2 Goals

SCUBA intends to develop semantic models for devices, systems and building management applications and will contribute to their standardisation to improve interoperability. SCUBA will provide a proof of concept of this approach by demonstrating how self-organisation will lead to simpler engineering, commissioning, and maintenance and how cooperation among heterogeneous, multi-vendor building monitoring and control systems will make the system more adaptive and robust in real building management applications. SCUBA addresses the challenges, including development of systems capable of dealing with complex, distributed and/or uncertain dynamics, development of self-organising, monitoring and control systems, providing methods for adjusting to/ recovering from failures, and standardisation of configuration interfaces and exchange platforms.

4.38.3 Approach

SCUBA follows a concurrent design workflow in which the research is performed in several extending cycles. Each cycle is terminated by a synchronized milestone that covers all involved work packages and ensures a high and simple measurability of progress.

First,**global requirements** are going to be collected, based on the expertise of industry partners. Based on these requirements the initial system architecture is detailed and common device and service semantics will be defined. Then **two research cycles** investigate the methods and tools to realize this architecture. Each research cycle contains a research, design, implementation, and a verification step to ensure a high development quality following a V-model. The results of each cycle are validated during the next cycle in a proof of concept step running in parallel to ensure a high result quality. Therefore, an additional refinement phase is added after the second research cycle to validate and improve also its results and ensure a high quality of the final results.

Knowledge gained during the proof of concept and the research cycles is fed back into the refinement of the initially defined requirements, architecture and semantic models to create a highly developed and validated architecture and semantics for standardisation.

The results of the research cycles are then fed into a final proof of concept phase to prove their practical value and resolve detected issues. This stepwise approach provides several mechanisms to control project progress and check result quality by validation within the tasks and at the end.

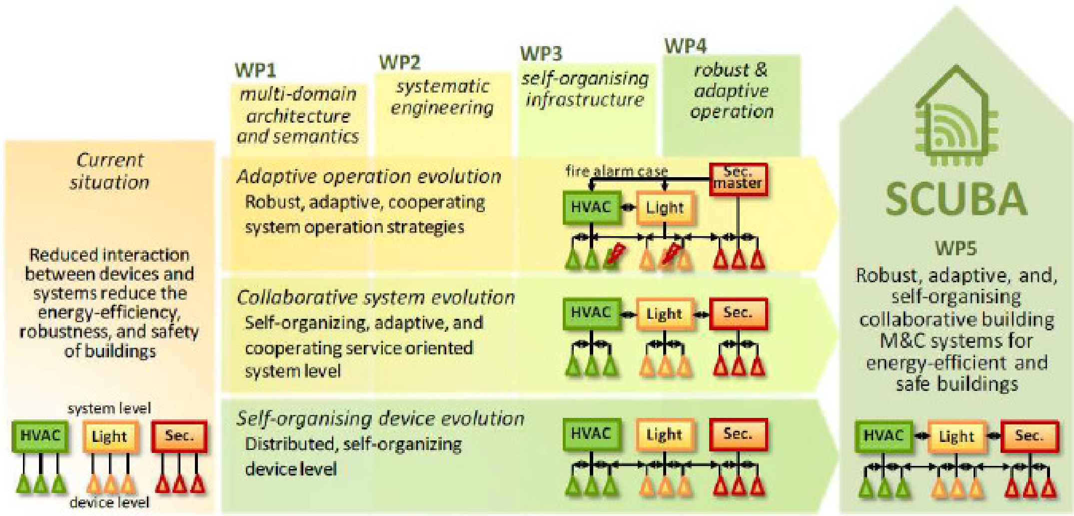


Figure 4.11: SCUBA work packages and approach.

SCUBA will use one of HOMES' seven integration platforms (Meylan Two Offices Office Building Inte-gration platform) and one of its five pilot sites (Chambry LAMA Office Building 1st floor).

Meylan is a proof of concept platform with typical BMS, controllers, sensors, electrical distribution and measurement devices for HVAC, lighting, and shading. It contains sensors, controllers and actuators from HOMES, Schneider Electric, TAC, CIAT, Philips, Somfy, Delta Dore. **The Chambry** building is designed to achieve the French architectural and environmental standards called HQE. It provides three fully adjustable office buildings with an area of 2580 m2. Each office room has air handling unit, ventilation grid, lighting, plugs and data connections monitoring temperature, comfort, and air quality in the office rooms. Additional sensors and equipment to evaluate and monitor the building's energy performance were added to the existing equipment.

4.38.4 Outcomes

European companies have a share of 46% in the global building automation market. The targeted improvements by SCUBA in systems engineering, commissioning and operation will result in wider adoption and implementation of cooperative building automation systems and will result in improved competitiveness not only for the European building automation industry but also in partnership, enhance the capabilities of the European building industry.

Key features of the SCUBA project are:

1. Improvements of SCUBA include systems engineering, commissioning and operation of BMSs, as well as easier and more cost effective BMS retrofitting.
2. Reduction in wireless infrastructure deployment complexity and cost by over 20% and increase in wireless M&C communication robustness by 15%.
3. SCUBA will demonstrate in the building energy efficiency use case how cooperative building management will increase energy efficiency by at least 5% to 10% over the baseline case.

4.38.5 Relation to GREENERBUILDINGS

The SCUBA project has just recently started and therefore there are no results or plans that can be foreseen to be used in GREENERBUILDINGS project. On the other hand, one of the main goals of SCUBA is to demonstrate how self-organizing, heterogeneous, multi-vendor building monitoring and control systems will make BMS systems more adaptive and robust, which is related to the aims of GREENERBUILDINGS. This offers the possibility for a collaboration of GREENERBUILDINGS with the SCUBA project.

4.39 Alwen

4.39.1 Abstract

ALwEN is a Dutch funded research project in the domain of wireless sensor networks. The ALwEN project stands for Ambient Living with Embedded Networks, the combination of body sensors, ambient sensors, wireless networks and telemedicine implements a novel approach to zeroth, first and second line care and addresses the widely recognized fact that care must be organized differently.

4.39.2 Goals

The aim of ALwEN is to enable the industry to develop and deploy wireless sensor networks very quickly. In order to achieve this goal a chip, framework and tools should become available in order to generate solutions in different application domains. The scope of ALwEN should be limited to the networking and associated framework and tools.

4.39.3 Approach

One important aspect of ALwEN's approach is to limit the network scope to the gossip network. All other aspects of the network are considered part of the application domain.

4.39.4 Outcomes

Several large scale experiments with more than 1000 wireless nodes have been carried out to evaluate lower power concepts (e.g. transceiver circuit), the gossip protocol, security aspects, the reference architecture and to evaluate the methods and tools for fast WSN system synthesis.

4.39.5 Relation to GREENERBUILDINGS

Many of the application domains considered in Alwen, do not intersect with requirements of GREENERBUILDINGS. However, the use of low power wireless nodes in large numbers, fits well with the technical needs of GREENERBUILDINGS. Thus, GREENERBUILDINGS can anticipate novel WSN approaches to enable the challenging scalability requirements based on the developments of ALwEN.

	Domotics & Building operational services	Sensors & Wireless Technology	Context & Activity Recognition	Middleware & compositional approaches	System Architecture	Smart Grid
Energy efficiency	Low	High	Low	Low	Low	Low
Scalability	Low	High	Low	Low	Low	Low
Costs	Medium	High	Low	Low	Low	Low
User comfort	Low	Low	Low	Low	Low	Low
Adaptability	Low	High	Low	Medium	High	Low
System reliability	High	High	Low	High	Medium	Low
Dynamicity	High	High	Low	Low	Low	Low
Standard Compliance	Low	Medium	Low	Low	Low	Low

Table 4.38: ALwEN relations.

Chapter 5

Standards and Techniques

This chapter describes standards and techniques are of interest and are possibly used in GREENERBUILDINGS. Each section gives a short description plus an overview of the areas in which this standard or technique relates to GREENERBUILDINGS. At the end, selected scientific concepts and techniques are included to illustrate further interrelations of GREENERBUILDINGS with existing concepts.

5.1 NesC

5.1.1 Abstract

nesC [nwp] (network embedded systems C) is a component–based, event–driven programming language used to build applications for the TinyOS platform. TinyOS is an operating environment designed to run on embedded devices used in distributed Wireless Sensor Networks. nesC is a dialect of the C language optimized for the memory limits of sensor networks. It is built as an extension to the C programming language with components ‘wired’ together to run applications on TinyOS.

5.1.2 Relation to GREENERBUILDINGS

nesC is relevant to Wireless Sensor Network Programming. Next we consider the characteristics of nesC with respect to the relations to GREENERBUILDINGS.

- **Energy Efficiency:** nesC puts CPU to sleep whenever the task queue is empty. Programming convention allows subsystems to be put in idle state.
- **System Reliability:** Restrictions on the programming model allow the nesC compiler to perform whole–program analyses, including data–race detection (which

improves reliability) and aggressive function inlining (which reduces resource consumption).

- **Standard compliance and Scalability:** nesC and TinyOS have been adopted by a large number of companies and sensor network research groups.
- **Costs:** nesC is an open source programming language. The license to be used for nesC is GPLv2 [wpb].

5.2 LiteOS

5.2.1 Abstract

LiteOS [owpf] is a real–time operating system (RTOS) from University of Illinois for use in sensor networks. LiteOS is a UNIX–like operating system that fits on memory–constrained sensor nodes. This operating system allows users to operate wireless sensor networks like operating Unix, which is easier for people with adequate Unix background. LiteOS provides a familiar programming environment based on UNIX, threads, and C. It follows a hybrid programming model that allows both event–driven and thread–driven programming. LiteOS is open source, written in C and runs on the Atmel based MicaZ and IRIS sensor networking platform.

5.2.2 Relation to GREENERBUILDINGS

LiteOS is relevant to Wireless Sensor Network at the Pervasive layer. Next we consider the characteristics of LiteOS with respect to the relations to GREENERBUILDINGS.

- **Adaptability, Dynamicity, Standard compliance and Scalability:** LiteOS supports C programming and provides Unix–like abstraction for wireless sensor networks, which greatly improved their compatibility with other development platforms and simplified the sensor network programming.

  While TinyOS and its extensions have significantly improved programmability of mote–class embedded devices via a robust, modular environment, NesC and the event–based programming model introduce a learning curve for the most developers outside the sensor networks circle. The purpose of LiteOS is to significantly reduce such a learning curve.

  It is an interactive and reliable model which provides the benefits like robustness, integrity, availability. It helps to provide the simple operations for services when compared to TinyOS model. LiteOS provides the environment for Object–oriented languages which helps to have the advantages like reusability, modularity, extensibility.

LiteOS includes three subsystems: LiteShell, LiteFS (File System), and LiteOS Kernel. These subsystems provide several desirable features for sensor network users and developers: (1) a hierarchical file system and a wireless shell interface for user interaction, (2) kernel support for dynamic loading and multi–threaded execution, and (3) online debugging, dynamic memory, and file system assisted communication stacks. These features are handy for the design and implementation of web services for sensor networks.

- **Costs:** LiteOS stems from the academia and is an open source project.

5.3 SkipGraphs

5.3.1 Abstract

Skip graphs [AS03] are a distributed data structure, based on skip lists, that provide the full functionality of a balanced tree in a distributed system where resources are stored in separate nodes that may fail at any time. They are designed for use in searching peer–to–peer systems, and by providing the ability to perform queries based on key ordering, they improve on existing search tools that provide only hash table functionality. Unlike skip lists or other tree data structures, skip graphs are highly resilient, tolerating a large fraction of failed nodes without losing connectivity. In addition, simple and straightforward algorithms can be used to construct a skip graph, insert new nodes into it, search it, and detect and repair errors within it introduced due to node failures.

Skip Graphs provide a way to maintain a distributed graph of resource keys. They satisfy:

1. Fast lookup of a node based on its resource key
2. Fast lookup of a range of keys
3. Ability to adjust to changes: insertion, deletion, and failure
4. Robust to a large fraction of node failures
5. Good load balancing even around “hot spots”

5.3.2 Relation to GREENERBUILDINGS

In GREENERBUILDINGS, we investigate Skip Graphs in terms of overlay network architectures with focus on the way they can be used for designing System Network Architecture. Next we consider the characteristics of skip graphs with respect to the relations to GREENERBUILDINGS.

- **Dynamicity:** Skip graphs are structured P2P systems that provide dynamicity properties. They support dynamic node addition and deletion that are performed in logarithmic time. In particular, Skip graphs are capable of tolerating both random failures, where an adversary chooses at random a node to fail, and adversary failures where an adversary chooses a specific node to fail after observing the structure of the skip graph. In both cases, skip graphs are unlikely to be disconnected.

- **Security and Privacy:** To the best of our knowledge, issues of security and privacy are not directly addressed by skip graphs. In particular the authors claim that an interesting extension of their work would be that to evaluate the behavior of the network in the presence of Byzantine failures. No other mention of encryption or access control techniques can be found in the literature.

- **Costs:** Skip Graph has been proposed without a specific implementation. The Department of Computer Science at Johns Hopkins University has used it, for experimental purposes, but currently no commercial or open source implementation is available.

5.4 Jini

5.4.1 Abstract

Jini technology [owpd] was introduced by Sun Microsystems and later transferred to Apache under the incubator project named River. Jini technology is an architecture based on the service-oriented computing. The purpose is to have a flexible and easily administered distributed system with which resources (hardware devices, software programs, or a combination of the both) can be found by human and computational clients. A Jini system or *federation* is a collection of services all communicating by using a service protocol.

The Jini system consists of three categories of components: infrastructure, programming model, and services. The infrastructure is the set of components that enables building a federated Jini system. The programming model is a set of interfaces that enables the construction of reliable service.

The most important concept within Jini architecture is a service–an entity that can be used by a person, a program, or another service. Service may be a computation, storage, a communication channel to another user, a software filter, a hardware device, or another user. Services are found and resolved by a lookup service. Services register with lookup services, and clients use them to find services they are interested in. This is enabled by a pair of protocols called discovery and join.

Access to many of the services in the Jini system is lease based. A lookup service will not want to keep a service forever, because it may disappear. As a result, a lookup service will grant a lease saying that it will only keep information for certain period of time, and the service can renew the lease later if desired [New06].

5.4.2 Relation to GREENERBUILDINGS

Jini technology is relevant to Software Architectures and Middleware field. Next we analyze the characteristics of Jini with respect to the relations to GREENERBUILDINGS.

- **Energy efficiency:** It is assumed that every Jini device has some memory and processing power. Device without processing power or memory should be controlled by another hardware/software device. Jini does not attempt to address energy efficiency issues.
- **Dynamicity & Scalability & Adaptability:** As a service-oriented architecture, Jini ensures a dynamic nature of the group of users and resources by enabling the ability to add and delete services flexibly. Jini technology can be used to build adaptive network systems that are scalable, evolvable and flexible as typically required in dynamic computing environments.
- **Security & Privacy:** The Jini security model is built on the twin notions of a principal and an access control list. Jini services are accessed on behalf of some entity (the principal) which generally traces back to a particular user of the system. Services may request access to other services based on the identity of the object that implements the service. Whether access to a service is allowed depends on the contents of an access control list that is associated with the object. Integrity, authentication and confidentiality can be managed within Jini.
- **Costs:** The licensing model for Jini is an open source Apache license.
- **System reliability:** The programming model as a part of the Jini system, supports and encourages the production of reliable distributed services. Jini provides a fair stable and fault-tolerant solution.
- **Data security:** Jini is protocol agnostic, but is implemented most of the times using RMI or CORBA communications protocol. Jini has a minimal set of protocols that allows objects to be passed through the connection.
- **Standard compliance:** Jini is a specification of a set of middleware components, including an application programming interface (API). Jini standards are created and agreed upon by the Jini Community as a means to share common strategies to achieve particular goals. It does not mean that anyone–not even authors of another proposal or standard–is required to use the mechanism to achieve those goals. Standards are intended for use by developers as guidelines when developing software using Jini technology. There are many successful projects using Jini [puJ].

5.5 NIST Smart Grid Standardization process

5.5.1 Abstract

National Institute of Standards and Technology (NIST) efforts to work on the Smart Grid [wpe] topic have roots on The Energy Independence and Security Act of 2007 that assigned to the NIST the role to coordinate the development of a framework to achieve interoperability of Smart Grid devices and systems.

NIST is involved together with the GridWise Architecture council from the U.S. Department of Energy to develop reports to the U.S. Congress about the status of standards of the electric Smart Grid. These institutes have formed different Domain Expert Working Groups (DEWGs) focused on specific topics of the Smart Grid interaction. The major areas of interest of the DEWGs are:

- Transmission and Distribution
- Building to Grid
- Industry to Grid
- Home to Grid
- Business and Policy

Nonetheless an important aspect NIST has to deal with, is security in the Smart Grid. To address this topic a special Cyber Security Coordination Task Group has been created.

5.5.2 Relation to GREENERBUILDINGS

The main scenarios of applications of NIST framework consider all the aspects related to the Smart Grid therefore the output of NIST efforts are relevant for the interconnection with Smart Grid part of the GREENERBUILDINGS project. Among the many DEWGs the most relevant in the context of GREENERBUILDINGS project for the interaction with the Smart Grid are:

- **Energy efficiency:** The Home-to-Grid DEWG (H2G DEWG) that investigates communications between utilities and home devices to facilitate demand response programs that implement energy management.
- **Scalability, Dynamicity & Adaptability:** There are various relevant aspects in terms of Scalability, Dynamicity and Adaptability:

- The Building-to-Grid DEWG (B2G DEWG) that investigates how commercial building may interact with the electric Grid, the energy service provider as well as other Grid-side service partners in order to let commercial buildings participate in energy markets and perform effective energy conservation and management. More generally the aim is to identify and enable every role that the commercial buildings can play in the future Smart Grid.
- In [Off10], NIST proposes a vision of the elements that need to interact with the Smart Grid. They identify two logically separated entities that might result important for the way GREENERBUILDINGS project can approach the interaction with the Smart Grid:
  - Meter: the meter envisioned by NIST is indeed a Smart Meter with standard functionalities such as measure, record, and communicate energy usage, but also advanced ones such as autonomously manage outages maintenance functions. This meter is also able to measure the flow of power into the Grid from distributed generation or storage resources at customer side.
  - Energy Services Interface (ESI): the functions provided by ESI are related to higher level services, ESI is a sort of information management gateway that enables the customer and its devices to interact with energy service providers. The fundamental functions of the ESI include demand response signaling as well as give the customer energy usage information. Therefore to achieve these goals the standards associated with the ESI need to be flexible and extensible to allow for innovation in market structures and services.

5.6 Open Smart Grid user group

5.6.1 Abstract

The Open Smart Grid user group (OSGug) [owph] is a consortium created by several companies to promote enhanced functionality, lower costs and speed market adoption of Advanced Metering networks and Demand Response solutions. The aim is the development of an open standards–based information and data model, together with reference design and interoperability guidelines. Therefore the objectives of the (OSGug) are to:

- Enable the broad adoption of advanced metering and demand response.
- Provide a definition of “open standards” in the area of advanced metering infrastructures and demand response solutions.
- Reduce the risks and problems both technical and functional for the various actors involved in Smart Grid such as utilities, regulators and ratepayers.

- Provide consumers with tools to create awareness on their energy use in order to have a better management of the same energy.

- Feed industry innovation, efficiency and reduction in cost of the solutions.

5.6.2 Relation to GreenerBuildings

The activities of the OSGug are divided into several subgroups that specifically deal with parts of the broader and complex Smart Grid system and therefore each groups deals with potential scenarios of interest.

- **Energy efficiency:** In terms of energy efficiency, subgroup **OpenHAN** that is involved in defining the principles, requirements, use cases and suggestions for the Home Area Network (HAN) in which primarily the interaction is between devices inside the premise. The aim is to enable an improved energy management.

- **Scalability, Dynamicity & Adaptability:** In terms of scalability, dynamicity and adaptability, there are three subgroup are working on these issues:

  – **OpenAMI** (open Advanced Metering Infrastructure – AMI) defines systems requirements, policies, principles, best practices, and services for information exchange and control between AMI related systems and utility enterprise front and back office systems. It is therefore developing a set of utility-based requirements and specifications for companies to adopt and for vendors to implement.

  – **OpenADE** (open Automatic Data Exchange – ADE) defines systems requirements, policies and principles, best practices, and services, required for information exchange and control between third party energy usage data service providers, public utility web services, and customers. OpenADE is developing a set of utility-ratified requirements and specifications. The aim is to develop an open and interoperable data model to be used in sharing data for utility, third party energy service companies and customer applications.

  – **OpenADR** (open Automated Demand Response – OpenADR) aims to define systems requirements, policies and principles, best practices, and services, required for business. In addition it deals with data requirements for standardizing control and pricing signals for demand response and distributed energy resources as part of the Smart Grid infrastructure. The compliance to the requirements enables the interactions and exchange of information to facilitate the demand response interaction and enables the exchanges between different actors such as utilities, independent system operators, aggregators, energy service providers and end use customers.

- **Security & Privacy:** Related to the security issues Open Smart Grid has also a task force to deal with these aspects: AMI-SEC TF (Advanced Metering Interface Security Task Force) whose aim is to create technical specifications for utilities in order to guarantee security while providing their services. In addition to utility, the specifications are relevant for OpenAMI task force as part of the AMI/DR specification, and by companies that want to produce secure Smart Grid related technologies.

5.7 EnOcean

5.7.1 Abstract

EnOcean is a wireless energy harvesting technology that is primarily being used in building automation systems. Originally, the concept was developed to enable wireless sensors and switches without batteries. The EnOcean wireless standard uses 868 and 315 MHz to transmit signals.

To harvest energy, electromagnetic energy converters, piezogenerators, solar cells and thermocouples are used among others. The EnOcean alliance is developing specifications for the interoperability of the sensors.

5.7.2 Relation to GreenerBuildings

EnOcean technology is very interesting to GreenerBuildings as it allows the development of sensors that are wireless and do not require batteries. Furthermore, the already available products (wireless light switches, wireless thermostat control, ...) could be utilized by GreenerBuildings as well, as they allow you to directly monitor user control. EnOcean contributes to the following areas.

- **Energy efficiency:** EnOcean was designed to allow energy efficient sensing and data transmission for things like light switches. Batteries are not used. Instead, energy is harvested from the environment. This is made possible by the low power wireless protocol that requires only 0.12 μWs.
- **Scalability:** The EnOcean protocol allows for over 500 closely located transmitters to operate. This allows for an installation with a high density of sensors as required for GreenerBuildings.
- **Costs:** Due the long lifetimes of EnOcean technology, replacement costs are reduced. Also, since EnOcean technology does not require batteries, maintenance costs are low.

5.8 BatiBUS

5.8.1 Abstract

BatiBUS is a relatively simple low cost protocol not relying on dedicated chips. The connection structure allows any arrangement of cables making it extremely flexible in matching building requirements. A large number of devices may be connected to the network using simple guidelines to maintain reliability of exchange. The same guidelines ensure that the time taken for messages to arrive at their destination remains imperceptible to the user. The media used is a twisted pair cable with a 15 V line voltage and addresses are assigned as part of the commissioning process. The philosophy of BatiBUS is to make all the devices catch transmissions from the other devices. All these devices process the received information, however only the ones programmed for managing the message, will filter the frame and will send this information to the application running on the device.

BatiBUS formed an alliance with the EIB and the EHS, in a unique European Standard for the automation of offices and homes.

5.8.2 Relation to GreenerBuildings

BatiBUS is not interesting to GreenerBuildings as the standard is not being used anymore today. Instead the followup of BatiBUS might be, which is called KNX. The following specifications relate to KNX.

- **Energy efficiency:** Several data point specifications of KNX refer to energy management related aspects (mainly smart metering).
- **Scalability:** KNX was designed to be used in large buildings.
- **Security & Privacy:** supported.
- **Costs:** medium/high.

5.9 Cyclon

5.9.1 Abstract

Cyclon protocol defines an unstructured peer to peer (P2P) network. It is unstructured in the sense that the P2P connections are chosen on some random basis. These connections are dealt with by the network overlay, which is shuffled every once in a while. This results in a network that is robust to failure of nodes since new connections can always be established through other nodes.

5.9.2 Relation to GREENERBUILDINGS

Cyclon allows for a robust network architecture that is robust to failure. This is a good property for GREENERBUILDINGS, since in large installations, failure of devices is something that has to be accounted for.

Cyclon addresses the following topics.

- **Scalability:** In principle there is no limit to the number of nodes in a Cyclon network, however, since peers are connected to each other and connections cannot be requested, connection to a specific peer in the network might not be easy.
- **Dynamicity & Adaptability:** A join process efficiently integrates a newly arrived node in the overlay, assuming that it knows initially about a Cyclon node that is already part of the system. Such a node can be located automatically, for instance, using expanding ring IP multicast, or be obtained by the system administrator through outside channels. The total cost for a node join, in terms of the number of messages exchanged, is constant and depends on both the size of the local view and the maximum number of steps for the initial random walks. Cyclon tolerate node failures at such a large degree that node departures are treated as failures assuming that a leaving node will not execute any procedure.
- **Costs:** Cyclon is an open protocol.

5.10 ZigBee

5.10.1 Abstract

Started by Philips, Honeywell, Invensys and followed by Motorola (now Freescale), Mitsubishi and up to 25 companies, the ZigBee is an industry standard which aims to create a bidirectional wireless communication standard to be used in inside devices for domotics, building automation, industrial control, PC peripherals and medical sensors.

The justification for the creation of this standard lies in the white spots that arise under the Bluetooth protocol, specifically the need to reduce complexity and cost. The ZigBee protocol allows data transmission rates from 20kB/s up to 250kBps, working in the 2.4GHz frequency using GSSS technology, is focused on low power consumption and ranges from 10 to 75m.

A ZigBee network can be formed of up to 255 nodes, most of which are in ”sleep” or lower power mode to increase their battery lifetime. For complete operation three types of devices are needed:

1. a ZigBee coordinator, which is the main node in the ZigBee network,

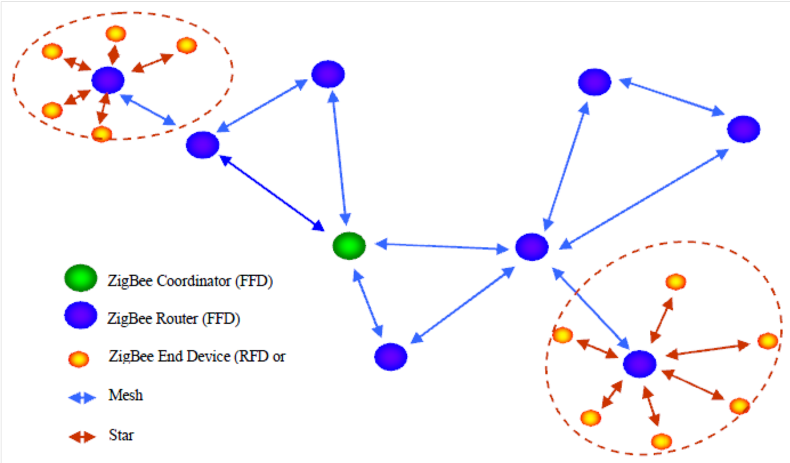


Figure 5.1: ZigBee Network

2. ZigBee routers which can forward data from other nodes, and

3. ZigBee end devices.

In the following figure the ZigBee protocol stack can be seen. ZigBee is much simpler than other protocols. The MAC and PHY layers are already defined by the IEEE 802.15.4 standard. NWK and application layers are defined by the ZigBee Alliance, making the application designer responsible of creating the code for the real application.

5.10.2 Relation to GREENERBUILDINGS

The ZigBee protocol is interesting to GREENERBUILDINGS because it allows energy efficient wireless communication. Especially the low current consumption in standby mode makes ZigBee devices ideal for low power devices. ZigBee contributes in the areas of wireless technologies, energy efficiency, scalability, data security and costs.

- **Energy efficiency:** ZigBee was designed to be an energy efficient competitor of Bluetooth. Nodes in sleep mode consume very little power, making devices with long standby times very energy efficient, with battery lifetimes of up to years.
- **Scalability:** Each ZigBee network needs one coordinator. In theory a ZigBee network can support up to 65000 nodes, but in practice the bandwidth is not large enough for this, making the practical maximum a few hundred devices depending on the application.
- **Security & Privacy:** High data security by 128 bit data encryption (AES Advanced Encryption Standard). This is optional and transmitted data is not necessarily en-

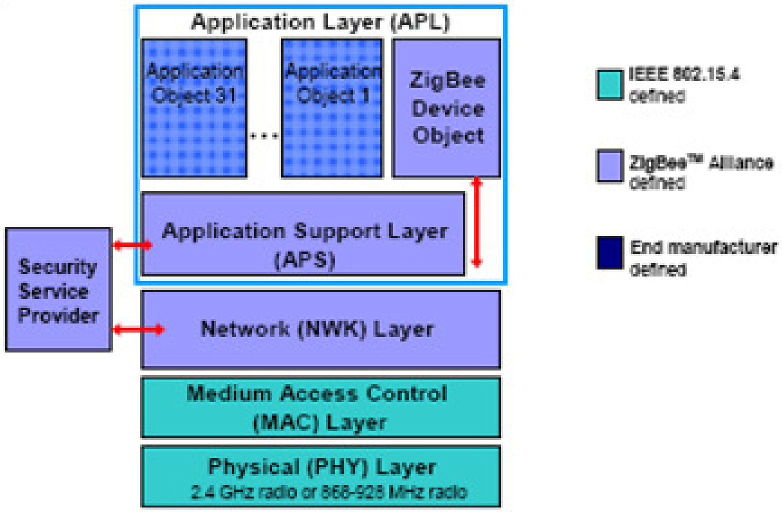


Figure 5.2: ZigBee Protocol Stack

crypted. AES is also used to check the integrity of the data using a 'Message Authentication Code' appended to the message.

- **Costs:** ZigBee was designed to be a low cost alternative to other wireless protocols.

While GREENERBUILDINGS aims to use open technologies whenever possible, the popularity of ZigBee based devices makes them a valid alternative for data gathering, acting as sensor data providers in the system.

5.11 Wireless HART

5.11.1 Abstract

The HART (Highway Addressable Remote Transducer Protocol) is a field bus implementation, and one of the most popular industrial automation digital protocols. This protocol was developed by Rosemount Inc. for smart field devices, and is an evolution from the open HART protocol which appeared in 1986. Since then, the protocol has had successive improvements that have revised the specification.

In September 2007 the Wireless HART standard was released as part of HART 7.0 specification. Since then, Wireless HART has gained acceptance as a valid wireless technology for process control.

Wireless HART features a mesh network specificallty aimed at automation applications. The greatest advantage of the protocol is that it adds wireless capabilities while maintaining compatibility with existing HART devices and infrastructures.

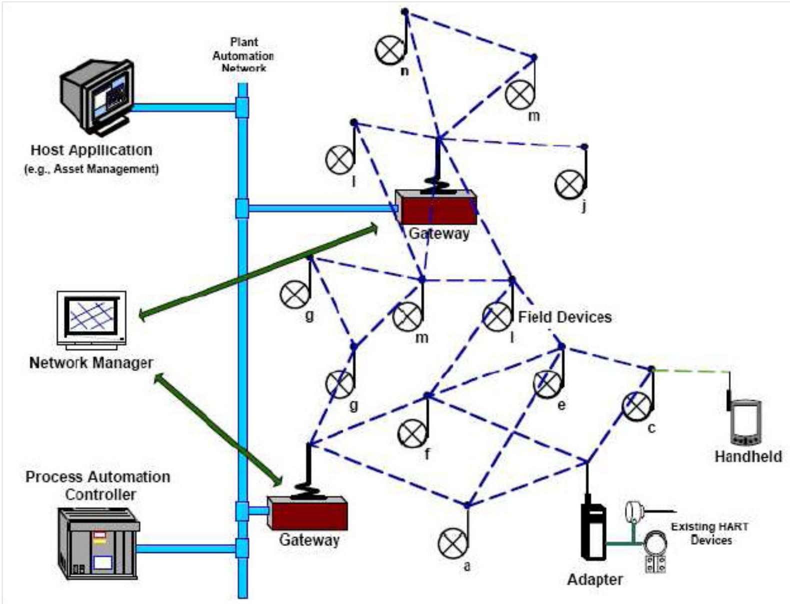


Figure 5.3: Wireless HART Network

A Wireless HART Network must contain compatible Wireless HART field devices, at least one Wireless HART bridge and one network controller. These components form a mesh network with bidirectional communication.

As happens with ZigBee, Wireless HART is based on the IEEE 802.15.4 physical layer. While ZigBee uses the existing IEEE 802.15.4 MAC, WirelessHART goes one step further to define its own MAC protocol. WirelessHART introduces channel hopping and channel blacklisting into the MAC layer, while ZigBee can only utilize Direct Sequence Spread Spectrum (DSSS) provided by IEEE 802.15.4. Thus, if a noise is persistent, which is not unusual in industrial fields, the performance of a ZigBee network might degrade severely. By changing the communication channel pseudorandomly, WirelessHART can limit the damage to minimum. Wireless HART operates in the 2.4GHz frequency.

5.11.2 Relation to GREENERBUILDINGS

Among other areas, Wireless HART contributes in scalability, adaptability, security and costs.

- **Scalability:** The topology of a WirelessHART network can be a star, a cluster or a mesh, thus providing much better scalability.
- **Adaptability:** Wireless HART permits reusing existing HART wired installations. In relation to GREENERBUILDINGS this possibility of making use of this advantage will rely in the characteristics of the Living Labs.

- **Security & privacy:** WirelessHART is a secure network system. Both the MAC layer and network layer provide security services. The MAC layer provides hop-to-hop data integrity by using MIC. Both the sender and receiver use the CCM mode together with AES-128 as the underlying block cypher to generate and compare the MIC. The network layer employs various keys to provide confidentiality and data integrity for end-to-end connections.
- **Costs:** Once more, reusing existing HART infrastructure greatly reduces the overall number of devices to be deployed. In that sense the overall costs of moving from a wired to a wireless infrastructure are reduced.

The Wireless HART protocol is based in the industrial automation world. The interest for GREENERBUILDINGS lies in the possible use of existing control installations for potential living-labs. If such an installation is available then the use of Wireless HART cannot be discarded.

5.12 SimpliciTI

5.12.1 Abstract

SimpliciTI is a low-power RF protocol aimed at simple, small RF networks. This open-source software is an excellent start for building a network with battery-operated devices using one of TI's low-power RF System-on-Chips (SoC) or the MSP430 ultra-low-power MCU and a TI RF transceiver. SimpliciTI was designed for easy implementation and deployment out-of-the-box on several TI RF platforms such as the MSP430 MCUs and the CC1XXX/CC25XX transceivers and SoCs. The sample applications run out-of-the-box on the SmartRF boards with CC2430EM and CC2520EM, as well as the MSP430FG4618/F2013 Experimenter Board with the CC1100EM, CC1101EM, or CC2500EM.

The latest version of SimpliciTI now supports the new CC2530 and CC430 solutions from TI.

Application based on SimpliciTI include alarm and security (occupancy) sensors, light sensors, carbon monoxide sensors, glass-breakage detectors, smoke detectors, automatic meter reading (gas meters, water meters, e-meters) or active RFID applications.

Key features are:

- Low power: A TI proprietary low-power network protocol
- Flexible - direct device-to-device communication, simple star with access point for store and forward to end device and range extenders to increase range to 4 hops
- Simple: Utilizes a five-command API

- Low data rate and low duty cycle
- Ease-of-use

5.12.2 Relation to GREENERBUILDINGS

If a network is needed, but the overall complexity of ZigBee is not a requirement, then this proprietary protocol from Texas Instruments is a good alternative. The SimpliciTI program enables the configuration of single and multihop (star and P2P with repeaters) networks. As it is compatible with TI family of inexpensive microcontrollers and radio chips, the overall cost of simple solutions can be low.

However, the main limitation of SimpliciTI is the maximum number of nodes per network, which is fixed at 30 nodes. This makes it difficult to address one of the main characteristics of GREENERBUILDINGS which require having a large number of nodes. Nevertheless, it is a nice alternative to test sensors before their final integration.

5.13 Z-wave

5.13.1 Abstract

Z-wave is a wireless protocol designed for home automation. It is optimized for low overhead commands such as on-off (switch) or raise-lower (thermostat). Furthermore, Z-wave is designed to be an energy efficient wireless protocol and low cost, and therefore lends itself for implementation in a lot of consumer products. Z-waves dynamic routing principle allows for a long range communication as each node acts as a router that extends the transmission range of all other nodes.

5.13.2 Relation to GREENERBUILDINGS

The Z-wave wireless and energy-efficient protocol lends itself to communication between nodes that do not have a large power source at their disposal. Therefore, this could be very interesting for GREENERBUILDINGS as relevant sensors and actuators have these properties.

- **Energy efficiency:** Z-wave was designed as an energy efficient solution for low overhead data transmission. The protocol and low power consumption make sure that energy usage is minimized.
- **Scalability:** There are no master nodes in a Z-wave network (all nodes are equal). Multi-hop routing makes sure that messages can be send over longer distances.

- **Dynamicity & Adaptability:** If a node fails, and there are other nodes available, messages can still be send due to the dynamic routing principle.
- **Costs:** Z-wave was designed to be low cost.

5.14 Wibree

5.14.1 Abstract

Wibree is a wireless protocol designed by the Nokia research center to address several perceived problems in wireless communication, most notably high power consumption. Although Wibree was developed to be an alternative to other protocols, especially Bluetooth, in 2007 it was included in the Bluetooth specification under the name Bluetooth low energy technology.

5.14.2 Relation to GREENERBUILDINGS

Wibree is now included in the Bluetooth specification making it obsolete. It is fully included in Bluetooth v4.0 as Bluetooth low energy technology.

- **Energy efficiency:** More energy efficient then other wireless protocols, especially Bluetooth.
- **Scalability:** One master node may communicate with up to 7 nodes in a piconet.
- **Security & Privacy:** Data encryption ensures secure transmission. However, Bluetooth is susceptible to denial of service attacks, eavesdropping, man-in-the-middle attacks, message modification and resource misappropriation
- **Costs:** As Bluetooth is a widespread standard, it is being produced in large quantities. This reduces the cost of Bluetooth devices. Moreover, Bluetooth is already available be default in a lot devices like phones, laptops and tablet PCs.

5.15 X10

5.15.1 Abstract

The X10 protocol is one of the oldest used in domotic applications. It transmits data by the low power lines with a very low speed (60 bps in USA and 50 bps in Europe).
There are three kind of devices X10, (i) orders transmitters, (ii) orders receivers, and (iii) orders transmitters and receivers. Transmitters direct up to 256 receivers. These receivers

contain revolving switches, one with 16 letters and other with 16 numbers, that permit assigning one of the 256 possible addresses. In the same installation,several receivers configured with the same address may coexist, though, all will perform the same preassigned function when a transmitters sends a frame to them. Any device receptor can receive from different transmitters. The bidirectional devices have the capacity of providing response and confirmation of the success from the order performance, this acknowledge is very useful when the system X10 is connected to an application that reveals the status of the domotic installation.

5.15.2 Relation to GREENERBUILDINGS

The following aspects make X10 suitable to be used in GREENERBUILDINGS as *Domotics and Building Automation* protocol:

- **Costs:** Due to the maturity and technology used, the products of X10 have a competitive price.
- **Dynamicity & Adaptability:** X10 is an international and open industry standard for communication among electronic devices.

5.16 UPnP

5.16.1 Abstract

The UPnP architecture offers pervasive network connectivity of PCs, intelligent appliances, and wireless devices. The UPnP architecture is a distributed, open networking architecture that uses TCP/IP and HTTP to enable seamless proximity networking in addition to control and data transfer among networked devices in the home, office, and everywhere in between. It enables data communication between any two devices under the command of any control device on the network [UPn].

UPnP enables data communication between any two devices under the command of any control host on the network.

5.16.2 Relation to GREENERBUILDINGS

The following aspects make UPnP suitable to be used in GREENERBUILDINGS as *Network Architecture and Protocol*:

- **Adaptability:** UPnP is media and device independent. UPnP technology can run on any medium including phone lines, power lines (PLC), Ethernet, IR (IrDA), RF

(Wi-Fi, bluetooth), and FireWire. No device drivers are used; common protocols are used instead. It is also operating system and programming language independent. Any operating system and any programming language can be used to build UPnP products. UPnP does not specify or constrain the design of an API for applications running on control points; OS vendors may create APIs that suit their customer's needs. UPnP enables vendor control over device UI and interaction using the browser as well as conventional application programmatic control.

- **Dynamicity:** UPnP allows the auto discovery devices in the network.
- **Standard compliance:** UPnP technology is built upon IP, TCP, UDP, HTTP, and XML, among others.

5.17 Zeroconf

5.17.1 Abstract

Zeroconf is a set of techniques that automatically create a usable IP network without the need for configuration or special servers. The techniques are enacted by the group of the same name created in the IETF in 1999 and whose aim is to standardize a series of protocols and procedures which allow the connectivity of computers in a network without the need for user intervention [Zer].

Zeroconf allows inexperienced users to connect computers, networked printers, and other network devices and expect a functioning network to be established automatically, without the need for configuration. Even a few simple services such as DHCP or DNS can be set in an easy way.

Zeroconf currently addresses three issues, namely:

- Avoiding choosing the range of addresses for a network (auto configuration).
- Finding out the name of a specific PC (name resolution).
- Finding out where to get certain services like printing (discovery of services).

These problems are solved according to various techniques that depend on the architecture used and the manufacturer of the devices and so on. There are several implementations of Zeroconf: some of them refer to the standards published by the group Zeroconf of the IETF and others still use techniques pending standardization. The most important implementations of these techniques are: Bonjour, Avahi, Windows CE 5.0 and Zeroconf IP (ZCIP).

5.17.2 Relation to GREENERBUILDINGS

The following aspect makes ZeroConf suitable to be used in GREENERBUILDINGS as *Middleware* technology:

- **Dynamicity & Adaptability:** the connection of a new devices to the IP network is managed by ZeroConf without any configuration procedure.

5.18 HIPERLAN/2

5.18.1 Abstract

HIPERLAN/2 (HIgh PErformance Radio Local-Area Network type 2) is a Wireless LAN standard developed by ETSI as an alternative to IEEE 802.11 standards. It supports asynchronous data and time-critical services that are bounded by specific time delays.
The air interface of the HIPERLAN/2 standard is based on time-division duplex (TDD) and dynamic time-division multiple access (TDMA) providing bit rates up to 54 Mbit/s. The chosen modulation scheme is Orthogonal Frequency-Division Multiple Access in the 5 GHz band. Each frame (with a fixed duration of 2 ms) contains fixed length control fields (where the access point communicate the time scheduling and mobile terminals ask for transmission resources) and variable length data fields.

5.18.2 Relation to GREENERBUILDINGS

- **Energy efficiency:** It supports power saving mechanisms where a mobile terminal requests the AP for a low power state and a specific sleep period.

- **Scalability:** It supports local areas of different sizes, ranging from a single radio cell (direct mode) to a building with a huge number of radio cells and different access points.

- **Dynamicity & Adaptability:** It is designed to offer Quality of Service (QoS) support and automatic frequency selection.

- **Security & Privacy:** It offers strong security features with support for individual authentication and per-session encryption keys.

5.19 IEEE 1394

5.19.1 Abstract

The IEEE 1394 interface is a standard serial bus interface. It supports asynchronous and isochronous data transmission modes. The isochronous mode is particularly interesting for real time applications, such as the direct acquisition from photo and video cameras. IEEE 1394 supports up to 63 devices, organized in a tree topology, and it allows peer-to-peer communications among devices. This last feature makes it suitable for ad-hoc computer networks.

5.19.2 Relation to GREENERBUILDINGS

- **Energy efficiency:** The power supply integrated into IEEE 1394 is sufficient to feed a large set of devices without the need of an external power source (except for computer or an IEEE 1394 hub).
- **Scalability:** IEEE 1394 compliant devices automatically arrange themselves (up to 63 devices) into an ad-hoc network without the need of external resources.

5.20 Human Activity Recognition Techniques

5.20.1 Abstract

In recent years the interest in techniques for human actions and activities recognition grows. *Actions* are characterized by simple motion patterns, typically executed by a single human. *Activities* involve coordinated actions between a small number of humans. A recent survey of human activity recognition techniques can be found in [TCSU08]. In the following, we will introduce some basic techniques actually used in the context of human activity recognition.

Nonlinear Dynamical Systems. Nonlinear Dynamical Systems (NDSs) [PRM00] represent the evolution of the *parametric* approach for modeling and recognizing *actions*. In these systems, actions are decomposed into a sequence of short segments and each of them can be modeled by using Linear Dynamical Systems (LDS) [CC07]. The switching between different LDS is driven by a switching function.

Probabilistic Petri Nets. Probabilistic Petri Nets [ACM+08] are graphical models used to characterize and recognize *activities*. They are an evolution of classical Petri

Nets [Pet66] which are particularly useful to model and visualize behaviors such as sequencing, concurrency, synchronization, and resource sharing.

Ontologies. Ontologies can be used to provide a uniform model of the activities. Ontologies allow interoperability, portability and represents a valid means to compare system performance. This standardization effort is the base of the Video Event Representation Language (VERL) [FNHB05], which provides an ontological representation of complex events in terms of simpler sub-events.

5.20.2 Relation to GREENERBUILDINGS

- **Energy efficiency:** A high level analysis of frequent human activities may suggests efficient power saving strategies.
- **Dynamicity & Adaptability:** Analysis of human action and activities may lead to the design of system whom behavior change dynamically in time, following user needs.
- **Security & Privacy:** Surveillance represents one of the most influent application areas of human activity recognition techniques.

5.21 Peer-to-Peer (p2p)

5.21.1 Abstract

A consortium of academic and industry leaders, defines P2P as the "sharing of computer resources by direct exchange." P2P systems have been used for sharing files (such as Napster [nap, CG01], Gnutella [QS02, gnu] and KaZaA [kaz]), for sharing communication links (such as Instant messaging and Voice-over-IP in Skype), and sharing computation (such as Seti@home). File sharing is the dominant P2P application on the Internet, allowing users to easily contribute, search and obtain internet content. P2P file sharing architectures can be classified by their *degree of centralization*, i.e., to what extent they rely on a server to facilitate the interaction between peers, into three categories: centralized, decentralized and hybrid.

Together with the evolution of decentralized and hybrid P2P systems the concept of *overlay networks* was introduced.

Overlay network architectures. An overlay network is a set of processes (or *nodes*), running on independent machines that can exchange messages through a communication network, and that cooperates at the application level to implement some services. Overlay networks can offer very simple services, like connectivity maintenance, or complex ones like reliable data storage, search and retrieval.

Overlay networks can usually be classified in three main families: *structured* [RD01, ZZJ+01, SMK+01, RFH+01], *unstructured* [JVG+07, VGvS05, ADH05, BGK+08, QS02] and *hybrid* [GBL+03].

5.21.2 Relation to GREENERBUILDINGS

Peer-to-Peer networks may be useful in GREENERBUILDINGS for the following motivations:

- **Dynamicity & Adaptability:** overlay networks are designed to let new nodes easily join the system while, at the same time, support nodes leaving it. The continuous arrival and departure of nodes from the system is called *churn*. All the existing overlay networks are also designed to tolerate node failures.
- **Scalability**: overlay networks have emerged mainly in an attempt to address the scalability issues that large scale P2P systems are faced with.
- **Dependability**: as previously stated, all the existing overlay networks employ some technique to survive to the failure of one or more nodes. Those overlays that also provide data storage/retrieval primitives (like the structured overlays) include mechanisms to prevent data losses or lookup disruption in case of failures.
- **Security & Privacy**: Some P2P systems such as the Freenet [SHGA06] allows some degree of anonymity, but generally they are weak in providing security and privacy.
- **Costs**: all of these systems are Open Source or scientific projects.

5.22 Bluetooth

5.22.1 Abstract

Bluetooth is a proprietary open wireless technology standard for exchanging data over short distances (using short wavelength radio transmissions) from fixed and mobile devices, creating personal area networks (PANs) with high levels of security. Created by telecoms vendor Ericsson in 1994, it was originally conceived as a wireless alternative to RS-232 data cables. It can connect several devices, overcoming problems of synchronization. Today Bluetooth is managed by the Bluetooth Special Interest Group.

5.22.2 Relation to GREENERBUILDINGS

Bluetooth technology could be implemented into GREENERBUILDINGS and used for the activity recognition. This aspect depends on the class of the device because of the range of the transmission and sensitivity, thus limiting it in some application. For example Class 3 has only 1 meter range.

- **Energy efficiency:** Consumption depends on the class of the Bluetooth device, in GREENERBUILDINGS Bluetooth Low Energy BLE can be considered (ca.15 mA)
- **Dynamicity & Adaptability:** Real-time location systems (RTLS), are used to track and identify the location of objects in real-time using Nodes or tags attached to, or embedded in the objects tracked, and Readers that receive and process the wireless signals from these tags to determine their locations
- **Security & Privacy:** Bluetooth implements confidentiality, authentication and key derivation with custom algorithms based on the SAFER+ block cipher. Bluetooth key generation is generally based on a Bluetooth PIN, which must be entered into both devices

5.23 Climate Talk

5.23.1 Abstract

ClimateTalk is a common information model developed for the exchange of information between disparate systems and devices. The basis of ClimateTalk was designed around standard communication protocol models, which allows for overall flexibility and expandability among numerous applications outside of HVAC. The open architecture also allows it to be adapted by any manufacturer. Designed to provide cost-savings, control and diagnostic capabilities for residential applications, ClimateTalk is standards-based and data-focused for simplified implementation. It also allows for independent decision-making within each device, providing flexibility, customization, and interoperability within a common framework.

5.23.2 Relation to GREENERBUILDINGS

The relationship to GREENERBUILDINGS are:

- **Energy efficiency:** ClimateTalk has been developed to facilitate communications between devices in residential buildings thus improving energy efficiency and cost-savings

- **Scalability:** the scalability of the technology for various applications (residential use, offices, public buildings)

- **Dynamicity & Adaptability:** ClimateTalk message sets can be expanded to accommodate many other control applications, such as air quality equipment, energy management systems and other applications that can benefit from advanced control and diagnostics capabilities, through a single network of communications

- **Costs & User Comfort:** the protocol is managed by the ClimateTalk Alliance [wpa] that is a non-profit open alliance of leaders and industry participants in the HVAC and Smart Grid ecosystem. Its mission is to enable interoperability of HVAC and Smart Grid devices as a means of saving energy and improving user comfort in the residential market for all stakeholders.

5.24 IEEE 1547.3

5.24.1 Abstract

IEEE 1547 (Standard for Interconnecting Distributed Resources with Electric Power Systems) is a standard of the Institute of Electrical and Electronics Engineers meant to provide a set of criteria and requirements for the interconnection of distributed generation resources into the power grid in the United States. The standard IEEE 1547.3 was published in 2007 and details for monitoring of distributed systems.

5.24.2 Relation to the GREENERBUILDINGS

The smart use of energy in buildings is a challenge inside GREENERBUILDINGS. One of the goal is to adapt the building to conserve energy acting dynamically. In this context the standard IEEE 1547 can be considered in order to optimize the distributed resources and the maintenance. This standard is also strongly considered into Smart Grid connections.

- **Energy efficiency:** IEEE 1547.3 promotes the interconnections between the distributed resources, improving maintenance, monitoring and control thus representing a consistent energy saving

- **Scalability:** IEEE 1547.3 is highly scalable and flexible

5.25 kelips

5.25.1 Abstract

A peer-to-peer (p2p) distributed hash table (DHT) system allows hosts to join and fail silently (or leave), as well as to insert and retrieve files (objects). Their system, called Kelips, uses peer-to-peer gossip to partially replicate file index information. In Kelips, (a) under normal conditions, file lookups are resolved within 1 RPC, independent of system size, and (b) membership changes (e.g., even when a large number of nodes fail) are detected and disseminated to the system quickly. Per-node memory requirements are small in medium-sized systems. When there are failures, lookup success is ensured through query rerouting. Kelips achieves load balancing comparable to existing systems. Locality is supported by using topologically aware gossip mechanisms. Initial results of an ongoing experimental study are also discussed.

5.26 OPC

5.26.1 Abstract

OPC is a widely accepted industrial communication standard that enables the exchange of data between multi-vendor devices and control applications without any proprietary restrictions. An OPC server can communicate data continuously among PLCs on the shop floor, RTUs in the field, HMI stations, and software applications on desktop PCs.

The Object Linking and Embedding for Process Control (OPC) Foundation is an industry consortium that creates and maintains standards for open connectivity of industrial automation devices and systems. The OPC standards specify the communication of industrial process data, alarms and events, historical data and batch process data between sensors, instruments, controllers, software systems, and notification devices. There are currently seven standards specifications completed or in development dedicated to interoperability in automation.

5.26.2 Relation to GREENERBUILDINGS

Since OPC standards has been successfully developed for many applications, especially into industrial automation sector, some OPC standards can be considered in the GREENERBUILDINGS, in particular considering that even when the hardware and software are from different vendors, OPC compliance makes continuous real-time communication possible.

- **Dynamicity & Adaptability:** data exchange between multi-vendor devices and control applications without any proprietary restrictions
- **Security & Privacy:** All the OPC servers provide information that is valuable to the enterprise and if improperly updated, could have significant consequences to plant processes. OPC Security specifies how to control client access to these servers in order to protect this sensitive information and to guard against unauthorized modification of process parameters.

5.27 UML

5.27.1 Abstract

Unified Modeling Language (UML) is a standardized modeling language in the field of software engineering. The standard is managed, and was created in 1996 by, the Object Management Group.

UML includes a set of graphic notation techniques to create, visualize and modify visual models of software-intensive systems . It models application structure, behavior, architecture, and also business process and data structure.

The UML main features can be summarize:

- As a general-purpose modeling language, it focuses on a set of concepts for acquiring, sharing, and utilizing knowledge coupled with extensibility mechanisms.
- As a broadly applicable modeling language, it may be applied to different types of systems (software and non-software), domains (business versus software), and methods or processes.
- As a tool-supported modeling language, tools are readily available to support the application of the language to specify, visualize, construct, and document systems.
- As an industry-standardized modeling language, it is not a proprietary and closed language but an open and fully extensible industry-recognized language.

5.27.2 Relation to GreenerBuildings

The approach proposed in the GreenerBuildings, is to develop a prototype by using a user centered and participatory approach, whereas the person is placed at the center.

The aim is to initially collect user requirements, and the Consortium will use a combination of use case modeling techniques for requirements expression together with traditional methods of documenting specific requirements. In this context UML can be considered a valuable tool to model use cases, helping to reach the specified objectives of the user centered approach within the GREENERBUILDINGS project: identification of different user groups, user scenario description, definition of the user and system requirements, specification of the use cases, and usability testing. UML is particularly suited to this kind of modeling and offers a standard way to visualize activities, actors, processes or software components.

- **Dynamicity & Adaptability:** UML is available with specific profiles tailored for specific areas, that is for business modeling, particular technologies, systems engineering, testing etc.
- **Costs:** UML is open and can be downloaded by website

5.28 LonWorks

5.28.1 Abstract

LonWorks [wpd] is a networking platform specifically created to address the needs of control applications. The platform is built on a protocol created by Echelon Corporation for networking devices over media such as twisted pair, powerlines, fiber optics, and RF. It is used for the automation of various functions within buildings such as lighting and HVAC.

5.28.2 Relation to GREENERBUILDINGS

The platform is standards compliant for building automation systems and includes the use of wireless technologies.

- **Energy efficiency:** Some relevancy
- **Scalability:** LonWorks is designed with scalability in mind.
- **User comfort:** LonWorks does not specifically provide innovative solutions in this area.
- **Dynamicity & Adaptability:** LonWorks does not preclude dynamic and adaptive control.
- **Security & Privacy:** Not known.
- **Costs:** TBD.

5.29 Contiki

5.29.1 Abstract

Contiki is a small, open source, highly portable, multitasking computer operating system developed for use on a number of memory-constrained networked systems ranging from 8-bit computers to embedded systems on microcontrollers, including sensor network motes. The name Contiki comes from Thor Heyerdahl's famous Kon-Tiki raft.

Despite providing multitasking and a built-in TCP/IP stack, Contiki only needs a few kilobytes of code and a few hundred bytes of RAM. A full system, complete with a graphical user interface, needs about 30 kilobytes of RAM.[citation needed]

The basic kernel and most of the core functions were developed by Adam Dunkels at the Networked Embedded Systems group at the Swedish Institute of Computer Science.

5.29.2 Relation to GREENERBUILDINGS

Since Contiki is lightweight enough for embedded applications, it offers a scalable means to provide building automation functions.

- **Scalability:** The fact that it is lightweight, makes it suitable for scaling
- **Costs:** Free

5.30 IEEE 802.11

5.30.1 Abstract

IEEE 802.11 is a set of standards carrying out wireless local area network (WLAN) computer communication in the 2.4, 3.6 and 5 GHz frequency bands. They are created and maintained by the IEEE LAN/MAN Standards Committee (IEEE 802). The base current version of the standard is IEEE 802.11-2007.

5.30.2 Relation to GREENERBUILDINGS

An enabler for support wireless connectivity for building automation, although not directly suited to very low power requirements for wireless sensor networks.

- **Scalability:** Can be considered scalable in the number of gateways needed for the GREENERBUILDINGS architecture

- **Dynamicity & Adaptability:** As a wireless protocol, the standard is widely adaptable to particular requirements.
- **Security & Privacy:** Full support for secure, private communications
- **Costs:** low/medium

5.31 EIB and KNX

5.31.1 Abstract

The European Installation Bus (EIB) is a standardized protocol and networking concept (according to EN 50090) for sensors and actuators in building environments. The successor of EIB is KNX, which is described below.

KNX is a standardized (EN 50090, ISO/IEC 14543), OSI-based network communications protocol for intelligent buildings. KNX is the successor to, and convergence of, three previous standards: the European Home Systems Protocol (EHS), BatiBUS, and the European Installation Bus (EIB or Instabus). The KNX standard is administered by the KNX Association.

Several communication media have been established for KNX, including twisted-pair cable (from BatiBUS and EIB), powerline (from EIB and EHS), radio (KNX-RF), infrared, and Ethernet. The most prevalent form is twisted-pair cable. KNX is designed to be independent of any particular hardware platform, thus can be implemented and managed through controllers of different complexity.

5.31.2 Relation to GreenerBuildings

As well as offering a standards compliant means for building automation applications, KNX also defines data point type relating to energy consumption and metering for energy visualization.

- **Energy efficiency:** Several data point specifications of KNX refer to energy management related aspects (mainly smart metering).
- **Scalability:** Scales to large buildings through separation of busses and support for different communication media.
- **User comfort:** Several metrics relate to user comfort, as sensors and actuators for monitoring and control using KNX are available.
- **Dynamicity & Adaptability:** These aspects are not precluded, though depend on selected communication media.

- **Security & Privacy:** Supported.
- **Costs:** Medium to high, due to complexity of the protocol and required controllers in sensors and actuators.

5.32 OSGi

5.32.1 Abstract

The OSGi framework is a module system and service platform for the Java programming language that implements a complete and dynamic component model. Applications or components (coming in the form of bundles for deployment) can be remotely installed, started, stopped, updated and uninstalled without requiring a reboot; management of Java packages/classes is specified in great detail. Application life cycle management (start, stop, install, etc.) is done via APIs which allow for remote downloading of management policies. The service registry allows bundles to detect the addition of new services, or the removal of services, and adapt accordingly.

The OSGi specifications have moved beyond the original focus of service gateways, and are now used in applications ranging from mobile phones to the open source Eclipse IDE. Other application areas include automobiles, industrial automation, building automation, PDAs, grid computing, entertainment (e.g. the Philips iPronto), fleet management and application servers.

5.32.2 Relation to GREENERBUILDINGS

Application of OSGi include building automation and energy monitoring using web service based platforms.

- **Energy efficiency:** some building automation and energy monitoring applications exist on top of OSGi
- **Scalability:** has been applied to telecommunications networks, so should be suited to this requirement.
- **Costs:** Free.

5.33 ws-notification

5.33.1 Abstract

WS-Notification is a group of specifications related to the WS-Resource framework that allows event driven programming between web services. WS-Notification is based on the event notification pattern. This pattern allows e.g. a web service to spread information to other web services, without prior knowledge of those web services.

5.33.2 Relation to GreenerBuildings

Eventing will be strongly required within the overall system architecture, which is likely to be web-service based.

5.34 BACnet

5.34.1 Abstract

BACnet [BAC] is a communications protocol for building automation and control networks. BACnet is an American national standard, a European standard, a national standard in more than 30 countries, and an ISO global standard. The protocol is supported and maintained by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standing Standard Project Committee 135. The protocol covers everything from what kind of cable to use to how to form a particular request or command in a standard way. What makes BACnet special is that the rules relate specifically to the needs of building automation and control equipment, i.e., they cover things like how to ask for the value of a temperature, define a fan operating schedule, or send a pump status alarm. The protocol defines three important things:

- **Services:** It defines a number of services that are used to communicate between building devices. The protocol services include Who-Is, I-Am, Who-Has, I-Have, which are used for Device and Object discovery. Services such as Read-Property and Write-Property are used for data sharing.

- **Objects:** It defines a number of Objects that are acted upon by the services. The objects include Analog Input, Analog Output, Analog Value, Binary Input, Binary Output, Binary Value, Multi-State Input, Multi-State Output, Calendar, Event-Enrollment, File, Notification-Class, Group, Loop, Program, Schedule, Command, and Device.

- **data link / physical layers:** this includes ARCNET, Ethernet, BACnet/IP, Point-To-Point over RS-232, Master-Slave/Token-Passing over RS-485, and LonTalk.

BACnet provides a standard way of representing the functions of any device, as long as it has these functions. Examples are analog and binary inputs and outputs, schedules, control loops, and alarms. This standardized model of a device represents these common functions as objects (collections of related information), each of which has a set of *properties* that further describe it. Each analog input, for instance, is represented by a BACnet *analog input object* which has a set of standard properties like present value, sensor type, location, alarm limits, and so on. Some of these properties are required while others are optional. One of the object's most important properties is its identifier, a sort of numerical name that allows BACnet to unambiguously access it. Once devices have common *appearances* on the network in terms of their objects and properties, it's easy to envision messages that can manipulate this information in a standard way.

5.34.2 Relation to GREENERBUILDINGS

The Project can take advantage of this standard as it is specifically designed for building automation and control. It provides good interoperability between different vendors. It can help in determining occupant behavior, and in the operation of Lighting, HVAC, office and home devices. It can also have an important role in achieving Objective 3. Given the above, this standard is of high relevance to the project.

- **Energy efficiency:** The technology by itself is useful in achieving energy efficiency, as it is specifically designed for communications and control of HVAC equipment.

- **Scalability:** The technique offers good scalability, and this is confirmed by real-world applications with deployments of thousands of devices

- **Dynamicity & Adaptability:** Adaptability and interoperability in possible because BACnet system allows multiple vendor systems to communicate 'mission critical' data to one another

- **Security & Privacy:** Network security in BACnet is optional. The intent of this architecture is to provide peer entity, data origin, and operator authentication, as well as data confidentiality and integrity. Other aspects of communications security, such as authorization policies, access control lists, and non-repudiation, are not defined by this standard. Systems that could require these functions may add them to BACnet using the proprietary extensibility features provided for by this architecture.

5.35 CORBA

5.35.1 Abstract

CORBA [COR] (Common Object Request Broker Architecture) is a standard defined by the Object Management Group (OMG) that enables software components written in multiple computer languages and running on multiple computers to work together. Using the standard protocol IIOP, a CORBA-based program from any vendor, on almost any computer, operating system, programming language, and network, can interoperate with a CORBA-based program from the same or another vendor, on almost any other computer, operating system, programming language, and network. CORBA is useful in many situations. Because of the easy way that CORBA integrates machines from so many vendors, with sizes ranging from mainframes through minis and desktops to handhelds and embedded systems, it is the middleware of choice for large (and even not-so-large) enterprises. One of its most important, as well most frequent, uses is in servers that must handle large number of clients, at high hit rates, with high reliability. CORBA works behind the scenes in the computer rooms of many of the world's largest websites; ones that you probably use every day. Specializations for scalability and fault-tolerance support these systems. But it's not used just for large applications; specialized versions of CORBA run real-time systems, and small embedded systems. CORBA applications are composed of objects, individual units of running software that combine functionality and data, and that frequently (but not always) represent something in the real world.

5.35.2 Relation to GREENERBUILDINGS

This is a standard that enables different software components to communicate. From this point of view, it could contribute mainly to the middleware of the architecture and help to communicate different devices that can support this technology.

- **Scalability:** Good scalability, as it is designed to work in large-scale applications
- **Dynamicity & Adaptability:** Good adaptability and interoperability, as it enables the communication between components from different computers and operating systems.
- **Security & Privacy:** This technology can help to provide security at application level.

5.36 IEEE 802.15

5.36.1 Abstract

IEEE 802.15 [802] WPAN is the 15th working group of the IEEE 802, and their effort focuses on the development of consensus standards for Personal Area Networks or short distance wireless networks. These WPANs address wireless networking of portable and mobile computing devices such as PCs, Personal Digital Assistants (PDAs), peripherals, cell phones, pagers, and consumer electronics; allowing these devices to communicate and interoperate with one another. The goal is to publish standards, recommended practices, or guides that have broad market applicability and deal effectively with the issues of coexistence and interoperability with other wired and wireless networking solutions. It is composed of 7 task groups, as follows:

- Task group 1: WPAN/Bluetooth
- Task group 2: Recommended Practices to facilitate coexistence of Wireless Personal Area Networks™ (802.15) and Wireless Local Area Networks (802.11)
- Task group 3: Standard for high-rate (20Mbit/s or greater), low-power and low cost WPANs
- Task group 4: Standard for low data rate solution with multi-month to multi-year battery life and very low complexity.
- Task group 5: determine the necessary mechanisms that must be present in the PHY and MAC layers of WPANs to enable mesh networking
- Task group 6: Standard optimized for low power devices and operation on, in or around the human body (but not limited to humans) to serve a variety of applications including medical, consumer electronics / personal entertainment and other
- Task group 7: chartered to write a PHY and MAC standard for Visible Light Communications (VLC)

5.36.2 Relation to GREENERBUILDINGS

Among the different standards defined under the IEEE 802.15.4 working group, it is particularly interesting the works done in the definition of it. 802.15.4 is a standard for Low Rate Wireless Personal Area Networks (LR-WPAN). The main purpose of this standard is to provide ultra low complexity, ultra low power consumption and extremely low cost wireless networking solution in low data rate networks. IEEE 802.15.4 intended to provide applications with relaxed throughput and latency requirements in WPAN. The IEEE 802.15.4 Working Group focused on the standardization of the bottom two layers of ISO/OSI protocol stack. There are two options for the upper layers definition: Zigbee protocols, specified by the industrial consortia ZigBee Alliance and 6LowPAN.

- **Energy efficiency:** Task group 4 (802.15.4) works towards providing ultra low complexity and low power consumption devices. Depending on the operating system running on the devices, it is possible to achieve extra levels of energy efficiency through software.
- **Scalability:** WPAN usually does not have good scalability. In the case of 802.15.4, as the network grow, collisions start to arise, ending up with slow data rates or, sometimes, with no communication at all. The workaround is to add more coordinators to the network.
- **User comfort:** As these standards are the technology enablers for home automation, they have a direct impact on user comfort.
- **Security & Privacy:** Security is very important, as these devices will be embedded in end-users equipment. Supplanting of, and tampering with devices should be avoided. Each standard provides the mechanisms for introducing security algorithms, but usually it will require doing it at software level.
- **Costs:** Low cost is one of the most important characteristics of personal area networks. Almost all the standards (with the exception of task group 1) are low cost

5.37 MODBUS

5.37.1 Abstract

MODBUS [Mod] is an application layer messaging protocol, positioned at level 7 of the OSI model that provides client/server communication between devices connected on different types of buses or networks. The industry's serial de facto standard since 1979, MODBUS continues to enable millions of automation devices to communicate. Today, support for the simple and elegant structure of MODBUS continues to grow. The Internet community can access MODBUS at a reserved system port 502 on the TCP/IP stack. MODBUS is a request/reply protocol and offers services specified by function codes. MODBUS function codes are elements of MODBUS request/reply PDUs.

It is currently implemented using:

- TCP/IP over Ethernet. .
- Asynchronous serial transmission over a variety of media (wire: EIA/TIA-232-E, EIA-422, EIA/TIA-485-A; fiber, radio, etc.)
- MODBUS PLUS, a high speed token passing network

5.37.2 Relation to GREENERBUILDINGS

Modbus can enable the communication and transportation of messages between devices of the architecture at application level. With the introduction of Modbus/TCP it is possible to have interoperability with multiple subsystems that are IP-compliant, but most probably this would happen at application level.

- **Scalability:** The adoption of an “open architecture” approach ensures that scalability becomes solely an issue of design logic as deployment is independent of practical constraints

- **Dynamicity & Adaptability:** Modbus makes it possible to integrate devices from different manufacturers into a common network system.

- **Security & Privacy:** There are no security elements in the Modbus protocol, over serial or TCP communications. Any attacker that can reach a Modbus server (slave) will be able to read and write to the device as well as reboot the device and run diagnostic commands

- **Costs:** As an open network technology, it presents low cost of deployment.

5.38 Pastry

5.38.1 Abstract

Pastry [Pas] is a generic, scalable and efficient substrate for peer-to-peer applications. Pastry nodes form a decentralized, self-organizing and fault-tolerant overlay network within the Internet. Pastry provides efficient request routing, deterministic object location, and load balancing in an application-independent manner. Furthermore, Pastry provides mechanisms that support and facilitate application-specific object replication, caching, and fault recovery.

Each node in the Pastry network has a unique, uniform random identifier (nodeId) in a circular 128-bit identifier space. When presented with a message and a numeric 128-bit key, a Pastry node efficiently routes the message to the node with a nodeId that is numerically closest to the key, among all currently live Pastry nodes. The expected number of forwarding steps in the Pastry overlay network is O(log N), while the size of the routing table maintained in each Pastry node is only O(log N) in size (where N is the number of live Pastry nodes in the overlay network). At each Pastry node along the route that a message takes, the application is notified and may perform application-specific computations related to the message.

5.38.2 Relation to GREENERBUILDINGS

Pastry could be useful for introducing group event notification or co-operative messaging. This could be helpful when there is a need to send messages/events to multiples nodes/devices of the network, or by having these nodes to collaborate together in the messaging system.

- **Energy efficiency:** Pastry, as an efficient routing algorithm, can help in saving energy of sensor nodes.
- **Scalability:** Very useful for group event notification when considering a large-scale deployment.
- **Costs:** It is a low cost solution as it is open-source based.

5.39 Meter-Bus and Wireless M-Bus

5.39.1 Abstract

M-Bus is a European standard (EN 13757), which is mainly used in gas and electricity meters. Nevertheless, the M-Bus can be used for alarm systems, illumination and heating control as well. The M-Bus standard is using a 2-wire interface (physical layer) and defines data link layer and application layer too. A master node in the network is used to collect the meter measurements. It was specifically developed for utility metering. A special radio-variant exists, called Wireless M-Bus.

5.39.2 Relation to GREENERBUILDINGS

- **Energy efficiency:** Metering devices us the standard, thus enabling energy monitoring and control functions.
- **Scalability:** Medium scalability. Both, wired and wireless variants can support multiple devices, however, may limit large-scale deployments.
- **Security & Privacy:** Not implemented.
- **Costs:** Relatively high costs, metering devices supporting the standard are limited, suggesting that the standard is not well-adoped compared to others.

5.40 ZigBee Smart Energy Profile

5.40.1 Abstract

ZigBee Smart Energy is the world's leading standard for interoperable products that monitor, control, inform and automate the delivery and use of energy and water. It helps create greener homes by giving consumers the information and automation needed to easily reduce their consumption and save money, too.

ZigBee Smart Energy version 2.0 is currently under development in cooperation with a number of other standards development groups. It will offer IP-based control for advanced metering infrastructure and home area networks. This version will not replace ZigBee Smart Energy version 1, rather it will offer utilities and energy service providers another choice when creating their advanced metering infrastructure and home area networks (HANs).

In addition to all the services and devices found in ZigBee Smart Energy version 1, version 2.0 will feature control of plug-in electric vehicle (PEV) charging, installation, configuration and firmware download for HAN devices, prepay services, user information and messaging, load control, demand response and common information and application profile interfaces for wired and wireless HANs

5.40.2 Relation to GREENERBUILDINGS

ZigBee Smart Energy [2.0] enables energy service providers and utilities to wirelessly communicate with and manage common household devices such as smart thermostats, in home displays and appliances. It improves energy efficiency by allowing consumers the means to manage their energy consumption more precisely using automation and near real-time information and additionally gives consumers the ability to choose interoperable energy saving products from a variety of different manufacturers and link them together. It also helps utilities and energy providers implement new advanced metering and demand response programs to drive greater energy management and efficiency, while responding to changing government requirements. Among other relations to GREENERBUILDINGS, Zigbee Smart Energy might enable an IP-based interoperability between different devices within the building automation field.

- **Energy efficiency:** Good applicability, as this technology is specifically designed for energy efficiency purposes
- **Scalability:** Medium scalability. ZigBee has some drawbacks when it comes to large-scale deployments.
- **Security & Privacy:** Good security implementations, as it is an important part of the different ZigBee profiles.

- **Costs:** Relatively high costs, as it is a proprietary technology belonging to the Zigbee Alliance.

5.41 Nonintrusive meter

5.41.1 Abstract

In order to improve the level of energy awareness, currently, a huge number of power sensors is required. As more sensors are used, the power consumption is increasing and the cost of energy awareness is rising. To reduce the number of power sensors and cost, a meter which can sense the operation of different appliances is proposed. This nonintrusive meter [Lee03] can effectively reduce the number of sensors for energy awareness and also the cost.

Afterwards, the next step is to change the operation mode due to the status of power network. However, most of the current domestic appliances do not offer this function to the users, and thus, the users might have to pay higher power bill if they did not change the operation mode of appliances during critical hours. It is hence proposed to develop the smart appliances in order to match up with the demand response program according the power network.

To integrate the nonintrusive meter and smart appliances, the propose of effective energy management can be feasible, and the cost of deployment can be reduced.

5.41.2 Relation to GREENERBUILDINGS

The energy awareness improvement is the first step of GREENERBUILDINGS, as it is critical to understand where and when the energy demand appears. However, for current existing solutions, the level of energy awareness relies on the number of power sensors. The nonintrusive meter can help to improve the level of energy awareness and not increase the cost. This meter can play an important role in the future EMS (Energy Management System) as well as GREENERBUILDINGS.

- **Dynamicity & Adaptability:** The nonintrusive meter is designed to incorporate metering functions for multiple devices. This allows for new devices to be installed without requiring separate measuring devices.
- **Scalability:** The reduction in the number of required sensors and meters allows for better scalability and installations are easier.
- **Costs:** Since less meters and sensors have to be deployed, overall costs are reduced. Installations are easier and require less effort.

5.42 ANSI C12.18

5.42.1 Abstract

ANSI C12.18 standard is a protocol specification standard developed by American National Standards Institute (ANSI) to provide an open-platform communications protocol for two-way communication with a metering device through an ANSI Type 2 optical port. The standard describes every detail of the physical attributes for optical communication ports (dimensions, LED wavelength, etc.). This standard is a very simple transport protocol, (layers 1 though 7 of the ISO/OSI model) designed to transport data structures such as the ones defined in ANSI C12.19 standard via the infra-red optical port in use by most North American electricity revenue meters. The aim of the standard was to build meters with a compatible communication interface. The standardization document also details the criteria required for communications with an electric power metering device by another device via an optical port. The other device could be a handheld reader, a laptop or portable computer, a master station system, a power metering device, or some other electronic communications device. electronic communications device.

5.42.2 Relation to GREENERBUILDINGS

This standard is important in the context of GREENERBUILDINGS since it might be used by meters and it could therefore be used to measure energy consumed in a building using devices that support the standard and use a ANSI Type 2 optical port (e.g., handheld reader, a laptop or portable computer, etc.)

- **Energy efficiency:** It is a optical communication standard related to metering devices, which provide the basis for energy optimisation.
- **Scalability:** Each meter needs a device with a compatible ANSI Type 2 optical port to obtain the measurements, thus cross-connect functionalities are needed to design larner networks.
- **Dynamicity & adaptability:** Limited adaptability since it only applies to meters that are compatible with the standard.
- **Security & privacy:** Security through password is provided by the standard and it is managed at the higher layer of the standards (i.e., session).
- **Costs:** Access to the standard specifications has a small cost. As an optical communication standard, hardware costs are substantial.

5.43 ANSI C12.19

5.43.1 Abstract

ANSI C12.19 defines a common data structure to use in transferring data to and from utility end devices, typically meters. Generally, C12.19 defines the table structure for utility application data to be passed between an end device and a computer. The standard does not define device design criteria nor specify the language or protocol used to transport that data. The purpose of the tables is to define structures for transporting data to and from end devices. The standard data structure of C12.19 is defined as sets of tables. The tables are grouped together into sections called decades. Each decade pertains to a particular feature-set and related function such as Time-of-Use, Load Profile, etc. Table data is transferred from or to the end device (typically a meter) by reading from or writing to a particular table or portion of a table. In the latest update of the standard additional formats for table in data exchange have been added such as XML-based.

5.43.2 Relation to GREENERBUILDINGS

The standard can be used to exchange information between the utility equipment (i.e., meter device) and applications developed in the GREENERBUILDINGS framework. This standard can mainly be used for the purpose of consumption data metering at building level.

- **Scalability:** Tables and data fields in the standard are fixed, but update of the standard adding more format have been realized.
- **User comfort** Improvement of meter reading procedures. Better operation for the customer and the utility officer.
- **Dynamicity & adaptability:** Limited adaptability since it only applies to devices that are compatible with the standard, although the standard has been updated.
- **Security & privacy:** The standards defines security tables which are used to hold areas for the placement of end device passwords and encryption/authentication keys used to establish group access permissions.

5.44 ANSI C12.21

5.44.1 Abstract

ANSI C12.21 standard provides an open-platform communications protocol for two-way communication with a metering device via a telephone modem. This standard details the criteria required for communications between a C12.21 Device and a C12.21 Client via a modem connected to the switched telephone network; it also provides the details for ISO/OSI 7 layers stack implementation. The C12.21 Client could be a laptop or portable computer, a master station system or some other electronic communications device. C12.21 does not specify the implementation requirements of the telephone switched network to the modem, nor does it include definitions for the establishment of the communication channel. The standard per se is quite general, but the inner purpose was to enhance the aspects defined in ANSI C12.18 in order to enable meter data reading remotely through a modem connection thus remotely. There is, in fact, a section of the standard specifically dedicated to electric metering.

5.44.2 Relation to GreenerBuildings

The standard can be used in the GreenerBuildings framework in order to remotely read the data of an energy meter compliant with this standard.

- **Energy efficiency:** No specific details are given. However data to be transferred are generally limited and C12.21 overhead is limited as well.
- **Scalability:** The specification are given for a point to point communication.
- **User comfort:** Improvement of meter reading procedures: better operation for the customer and the utility officer.
- **Security & privacy:** Security is an optional service, but it is provided by the standard. It is realized in the same manner as in C12.18. Encryption is supported but it is not defined by the standard, it must be implemented at application layer.

5.45 IEC 61107

5.45.1 Abstract

IEC 61107, formerly called IEC 1107, is an international standard that describes a widely-used computer protocol used to read utility meters in the European Union. It sends ASCII data using a serial port. The physical media are either modulated light, sent with an LED and received with a photodiode, or a pair of wires. The protocol is half-duplex. Although the standard does not defines which media or the procedure to perform the meter readings (optical and electrical interfaces are defined in the standard) the definition of the standard is related to local reading. Usually a person from the utility company presses a meter-reading gun against a transparent faceplate on the meter, or plugs into the metering bus at the mailbox of an apartment building.

5.45.2 Relation to GreenerBuildings

The standard can be used in the GreenerBuildings framework in order to read the data of an energy meter compliant with this standard.

5.45.3 Energy efficiency

No specific details are given. However data to be transferred are generally limited and IEC 61107 overhead is limited as well.

5.45.4 Scalability

The specification are given for a point to point communication with a meter, however the reader can connect to several meters (interacting separately with each one) if connects to the meters' bus.

- **User comfort:** Improvement of meter reading procedures: better operation for the customer and the utility officer.
- **Security & privacy:** the standard recognizes different level of security required in order to interact with a metering device: 1) Understanding of the standard; 2) one or more password are required to be entered correctly; 3) require operations on a sealed button or manipulation of data with a secret algorithm to obtain access; 4) physical access to device case and physical change (e.g., making/breaking a link or operation on a switch)

5.46 IEC 62056

5.46.1 Abstract

IEC 62056 is an international standard composed by a series of different standardization documents all dealing with the topic of meter reading. IEC 62056-21 describes hardware and protocol specifications for local meter data exchange. IEC 62056-31 describes architectures for local bus data exchange with stations either energized or not. IEC 62056-41 Describes a 3 layer data exchange architecture used for communication with large industrial and commercial customer's metering equipment (remote reading for billing purpose). The public switched telephone network (PSTN) is used as a communication medium for this data exchange. IEC 62056-42 specifies the physical layer services and protocols within the Companion Specification for Energy Metering (COSEM) three-layer connection oriented profile for asynchronous data communication. IEC 62056-46 defines the data-link layer for connection oriented HDLC-based, asynchronous communication profile. IEC 62056-47 Specifies the transport layers for COSEM communication profiles for use on IPv4 networks. IEC 62056-51 and IEC 62056-52 provide all the information specific to the management and communication protocol management of distribution line message specification (DLMS) server of the protocols described in IEC 62056-31, IEC 62056-41 and IEC 62056-51.

5.46.2 Relation to GREENERBUILDINGS

The standard can be used in the GREENERBUILDINGS framework in order to read the data of an energy meter compliant with this standard.

5.46.3 Energy efficiency

No specific details are given. However data to be transferred are generally limited.

- **User comfort:** Improvement of meter reading procedures: better operation for the customer and the utility officer.
- **Security & privacy:** The several parts of the standard consider security and privacy at the different level. Similar consideration as done with IEC 61107 can be done.

5.47 Google Power Meter

5.47.1 Abstract

Google Power Meter was a project developed by Google in order to raise awareness in the users about their energy consumption. The project was retired by Google on 16th September 2011. For the end user Google Power Meter gave the possibility to track energy consumption through a Google gadget in end user account. Google defined only a small set of requirements to be satisfied by the metering device (or a device acting as a gateway for the metering device) in order to integrate with the functionalities provided by Google:

- Data transmission through HTTPS.
- Request towards Google Power Meter API at most 6 times in an hour.
- Device must have a web browser.
- A token (used for security features) must be stored in the device.

- Deactivation of the device must be supported, in order for the customer to terminate the usage of Power Meter service.
- Only data representing electricity (even generated electricity, net consumption or device consumption) are allowed.

5.47.2 Relation to GREENERBUILDINGS

Unfortunately the Google Power Meter project was terminated. However, it provides solutions for visualizing energy consumption to users in GREENERBUILDINGS. Several alternatives are available such as “plotwatt”, “myEragy”, “it’s electric”, which may or not be coupled to specific meter gateways.

- **Energy efficiency:** The communication with Google Power Meter is quite simple and there are no particular overhead in data transfer to consider. A problem could be represented by the device acting as a gateway between the meter and the web which needs to be turned on and interact both with meter and web. However solution for energy efficiency, low power sleep mode and low power in communication between the gateway and the meter are available (e.g., Bluetooth ULP/4.0, Zigbee).
- **Scalability:** Subsections of a building, up to the single device were supported by Google Power Meter.
- **User comfort:** User is aware of the amount of energy he consumes.
- **Dynamicity & adaptability:** Google Power Meter service is no more available.
- **Security & privacy:** Google Power Meter required the communication to be encrypted by using HTTPS communication.
- **Costs:** Google Power Meter was free both for energy companies and customers. The only cost was related to a meter compliant to Google Power Meter requirements or a meter gateway towards the web.

5.48 OASIS standards for information exchange between buildings and the smart grid

5.48.1 Abstract

Within the Organization for the Advancement of Structured Information Standards (OASIS) two specifications have been developed for use in the interconnection between buildings and the smart grid: Energy Market Information Exchange [EMIX], Energy Interoperation [EI] and WS-Calendar [WS-Calendar]. The main focus of these standards is the specification of information models and associated information exchange schemes for interactions related to the trading, supplying, transporting and usage of electrical energy.

- **EMIX - Energy Market Information Exchange.** The Energy Market Information Exchange (EMIX) specification provides an information model for the exchange of information in transactive energy markets. The specification provides information models for prices and bids, the items or products which can be traded, options which give the buyer the right, but not the obligation to buy or sell a product, and the terms for trade and execution. The EMIX specification uses the information models from WS-Calendar for matters related to time, schedules, etc.

- **EI - Energy Interoperation.** The Energy Interoperation specification defines the information models and information exchange schemes useful for interaction between parties involved in a context of transactive energy (explicit trade in energy products in retail, wholesale and energy transport) and event based interactions (e.g. demand response with curtailment events).

  For contexts with transactive energy interactions, Energy Interoperation defines the concepts of tender being an offering of an EMIX product, quote as a response to tenders and transaction for the acceptance of the quote. In effect, Energy Interoperation provides herewith the means to build trade processes around the products and the underlying information model defined in EMIX.

  The Energy Operation provides many additional concepts for context wherein event based interactions take place such as in demand response environments. Much of the specification is based on the work done by Lawrence Berkeley National Laboratory on the Open Automated Demand Response specification [OpenADR]. The Energy Interop-eration specification contains an explicit OpenADR profile, which specifies how the standard is to be used to support the original OpenADR functionality.

  For event based interactions, the specification allows e.g. for registration of parties and enrolment in demand response programmes, delivery of event information, temporarily opting in or out of a programme and reporting of historic information (measurements, follow up on events, etc.) as well as future projections. The event information which can be exchanged using the specification ranges from price information and adjustments of rate of demand and supply to set-points for equipment.

- **WS-Calendar.** The WS-Calendar specification provides semantics on temporal aspects of schedules, intervals, events and other concepts related to time as well as an XML specification for expressions according in line with these semantics. Note that this standard is based on the IETF iCalendar specification.

  The may function WS-Calendar has for the Energy Market Information Exchange and the Energy Interoperation specifications is the ability to express when ‘things’ must or may occur. Examples include time-series of prices, schedules of production, the minimal lead time before exercising an option, etc.

A concept not seen in e.g. iCalendar is the concept of tolerance. This concept allows for expression of the tolerance to deviation from a basic temporal constraint such as an earlier start, a later end, etc. This concept is of use in scheduling energy products and demand response alike; e.g. to be precise in what temporal deviations are allowed or to deliberately smoothen response. For further information the reader is referred to [WS-Calendar].

5.48.2 Relation to GREENERBUILDINGS

The major relationship between the OASIS specifications related to Smart Grids and the GREENERBUILDINGS project lies in the coordination of the electricity consuming or producing activities within buildings on the one hand and the conditions of the electricity networks and markets on the other. The key in this interaction is that quantity and time of electricity consumption or production in buildings are flexibly adaptable.

The aforementioned specifications allow for a vast range of market contexts to be implemented from an information exchange perspective; here we distinguish between two main approaches:

1. the optimisation of operations of electricity consuming or producing activities based on prices, curtailment events and other information originating from the electricity market (e.g. an energy supplier),
2. the active engagement in trading of products on the electricity market; e.g. by selling or buying quantities on a market, providing ancillary services, etc.

The OASIS specifications relate to the GREENERBUILDINGS project according the performance metrics as follows.

- **Energy efficiency:** The reviewed OASIS specifications do not improve the energy efficiency of buildings. In fact this is more general characteristic of buildings interacting with the Smart Grid ? the use of these specifications and the business interactions supported therewith may degrade the energy efficiency of the building itself. The reason is that the OASIS specifications support optimisation on a higher level than a single building using flexibility of equipment in the building. The use of this flexibility may cause to be operation of this equipment on a sub-optimally from an energy efficiency point of view.
- **Scalability:** Scalability is not impacted directly by the OASIS specifications since they provide information models and no or limited specification of information transport nor any computations.
- **User comfort:** If equipment with flexibility is employed in a system based on these OASIS specifications, care must be taken to ensure user comfort. E.g. a heating

system may be turned off for such a long period because of a curtailment event that user comfort is impacted. The building control system must take such threats into account.

- **Security & privacy:** The Energy Interoperation and Energy Market Information Exchange specifications may be used to express sensitive information, so care must be given to this aspect when implementing systems based on these specifications. Security is not explicitly addressed by these OASIS specifications, however suggestions for the use of other specifications is given to ensure confidentiality, integrity and availability of information and functionality.

- **Costs:** The OASIS specifications may have a positive effect on the cost-effectiveness of a building when the specifications are used to provide services to the electricity market or when optimising electricity producing or consuming activities within buildings based on electricity market information.

5.49 oBIX

5.49.1 Abstract

oBIX (Open Building Information eXchange) is an industry-wide initiative to define XML- and Web services-based mechanisms for building control systems. oBIX will instrument the control systems for the enterprise. The purpose of oBIX is to enable the mechanical and electrical control systems in buildings to communicate with enterprise applications, and to provide a platform for developing new classes of applications that integrate control systems with other enterprise functions. Enterprise functions include processes such as Human Resources, Finance, Customer Relationship Management (CRM), and Manufacturing.

5.49.2 Relation to GreenerBuildings

This standard is important in the context of GreenerBuildings since building controls include all the smart systems embedded in buildings, systems that have traditionally been obscured by proprietary control standards and arcane details. Examples of building control systems include: heating, ventilation and air conditioning (HVAC), elevators, laboratory equipment, life/safety systems, access control, intruder detection, A/V event management, CCTV monitoring, and many others. oBIX also extends to non-control system sensing, providing real-time access to sensors including environmental sensing, electrical panels, and power meters, as well as other utility meters - anything that measures or monitors the physical space in a facility.

- **Scalability:** When control systems are instrumented using an IT standard like Web services, the largest asset of the enterprise–its facilities–are enabled to be fully available to business management.
- **Dynamicity & adaptability:** oBIX is useful for systems integration of systems and the ability for systems to provide relevant data to enterprise systems that many corporations now have.
- **Costs:** oBIX v1.0 has been accepted as a Committee Specification. oBIX v1.0 can be downloaded by the public. An open source JAVA toolkit for working with oBIX is being developed in parallel with the standard. THe JavA Toolkit for the standard can be downloaded from the oBIX Sourceforge repository.

5.50 OPen Connectivity-Unified Architecture (OPC-UA)

5.50.1 Abstract

Introduced in 1995, OPC enabled interoperability between Windows-based applications and process control hardware and software. The latest OPC specification, namely OPC-UA, has the aim to improve and unify the earlier specifications into a single coherent foundation.

OPC-UA is built around a ”Service Oriented Architecture” (SOA). Services are available to any remote application that has both the authority and the need to use it in a highly reliable way. In order to address security issues, interfaces must deliver both support for secure access and immunity to malicious attacks that may compromise an automation system. Furthermore, as an industry standard, the interface must leverage common technologies that are self-describing for improved ease of implementation, e.g., XML. Third party applications can connect to an OPC-UA service, pass information to it in a secured yet open and descriptive manner, and the service will provide a similar result. OPC-UA follows the concepts of a Web interface and because it behaves like any other Web interface, it works with firewalls and can be managed by system administrators. It allows you to define ports for service access and for network traffic control in a straightforward and predictable manner .

5.50.2 Relation to GREENERBUILDINGS

The following aspects make OPC-UA relevant as potential extension of the GREENERBUILDINGS framework to a Web interface:

- **Security & performance:** OPC-UA is built to meet needs of the automation industry. This makes it very effective in terms of both performance and security.

OPC-UA uses a compressed and binary data transfer, while managing secure access through Security Certificates. Finally, as any web interface, it is firewall friendly.

- **Standard compliance:** OPC-UA is build on open standards like XML.
- **Adaptability:** The UA specification is structured to be implementation independent and adaptable to new technologies. It uses cross-platform capable Web Services instead of DCOM

5.51 Device Profile for Web Service (DPWS)

5.51.1 Abstract

Devices Profile for Web Services (DPWS) is a Web Services profile that enables plug-and-play for networked devices. A PC or other device can detect DPWS-enabled devices on a network, then discover and invoke the Web service functionality each device provides. Its purpose is similar to Universal Plug and Play (UPnP), although it employs a Web Services model [Cor07].

In Web Services terms, a *profile* is a set of guidelines for how to use Web Services technologies for a given purpose or application. It enables secure Web Service messaging, discovery, description, and eventing on resource-constrained endpoints. Web Services standards allow implementers to choose from a variety of message representations, text encodings, transport protocols, and other options, some of which are not interoperable. By constraining these decisions, profiles ensure that conforming implementations will work well together [Cor07].

In the DPWS terminology a Device is a distinguished Service responsible for representation of the whole device and discovery and it can host several Hosted Services that provides desired functionality.

DPWS provides the following functionality between conforming devices [wik]:

- Discovery services: used by a device connected to a network to advertise itself and to discover other devices. Support of discovery has led some to dub DPWS as “the USB for Ethernet.”
- Metadata exchange services: provide dynamic access to a device’s hosted services and to their metadata.
- Publish/subscribe eventing services: allowing other devices to subscribe to asynchronous event messages produced by a given service.

The DPWS specification was initially published in May 2004 and was submitted for standardisation to OASIS in July 2008. DPWS 1.1 was approved as OASIS Standard together with WS-Discovery 1.1 and SOAP-over-UDP 1.1 on June 30, 2009.

5.51.2 Relation to GREENERBUILDINGS

The following aspects make DPWS relevant to GREENERBUILDINGS, e.g. as network architecture and protocol:

- **Adaptability:** DPWS is based on WS stack and then it is independent from the operating system and programming language. In addition, common protocol are used instead of specific device drivers.
- **Dynamicity:** DPWS allows devices' auto discovery, thus it is suited for dynamic environments.
- **Standard compliance:** DPWS is built on the following standards: WSDL 1.1, XML Schema, SOAP 1.2, WS-Addressing, and further comprises WS-MetadataExchange, WS-Transfer, WS-Policy, WS-Security, WS-Discovery and WS-Eventing.
- **Security:** WS-Security makes possible to have strong security features.

5.52 A pervasive network architecture featuring intelligent energy management of households [TMC+08]

5.52.1 Abstract

The authors introduce a network architecture that is designed to allow users to become more aware of their energy usage patterns, but also to allow users to make energy savings by controlling appliances from different terminals (computers, phones, ...). The architecture consists of two main parts. The first main part are the Energy Management Devices (EMDs). These functional entities allow all appliance types, energy monitoring and management function to communicate over the network in a generic way. The second part is the residential gateway called ESTIA. This device establishes the actual communication between appliances and energy monitoring management.

5.52.2 Relation to GREENERBUILDINGS

This network architecture is interesting because it allows a large number of different types of appliances to be represented in the network without a need to treat them all differently. It is specifically designed with energy saving information in mind. One disadvantage is that it is constructed for residential accommodations.

- **Energy efficiency:** The described network architecture is designed to allow appliances to be more energy efficient. On the one hand this is achieved by allowing users to access services from outside the home. On the other hand, the energy patterns of appliances is monitored and managed.
- **Scalability:** The network was designed for in home usage. Although it is not discussed in the paper, it is unlikely that the architecture will do well in larger setups. This is because there is one component that is responsible for controlling all devices simultaneously.
- **User comfort:** The network allows users to access home services from anywhere.
- **Security & Privacy:** Communication protocols are held responsible for security issues.

5.53 Developing a Building Energy Management Framework Based on Ubiquitous Sensor Networks [LYC10]

5.53.1 Abstract

The paper describes a building energy management system (BEMS). Ubiquitous sensor networks (USN) are used to monitor environmental conditions. In this paper an extreme case is described, as all employees are forced to take certain actions to save energy. For example, to optimize energy consumption due to light usage, users in a large office are forced to sit next to each other so that less lights have to be turned on. Similarly, air conditioning is only activated in key areas where more people reside.

5.53.2 Relation to GREENERBUILDINGS

Although a BEMS is interesting to GREENERBUILDINGS, the philosophy is different, since user comfort and building automation is not put in first place. Rather, users are forced to act in certain energy saving actions. Contributions of GREENERBUILDINGS are in the fields of context and activity recognition, software architecture, middleware and compositional approaches and system architecture to address this shortcoming.

- **Energy efficiency:** Energy is saved in various areas by forcing users to share various resources like lighting and heating. In GREENERBUILDINGS users will not be forced to act.
- **Scalability:** The system is only designed for a single room, and is unlikely to scale well to large installations.

- **User comfort:** The described system is likely to reduce user comfort.

5.54 Estimating building consumption breakdowns using ON/OFF state sensing and incremental sub-meter deployment [JS10]

5.54.1 Abstract

This paper considers the problem of estimating the power breakdowns for the main appliances inside a building using a small number of power meters and the knowledge of the ON/OFF states of individual appliances. First we solve the breakdown estimation problem within a tree configuration using a single power meter and the knowledge of ON/OFF states and use the solution to derive an estimation quality metric. Using this metric, we then propose an algorithm for optimally placing additional power meters to increase the estimation certainty for individual appliances to the required level. The proposed solution is evaluated using real measurements, numerical simulations and by constructing a scaled down proof-of-concept prototype using binary sensors.

5.54.2 Relation to GREENERBUILDINGS

This technique is useful because it allows for a scalable solution to monitor power usage. One disadvantage is that it is not obvious up front where meters have to be installed (that is the point of this paper), making it a difficult solution to apply in practice.

- **Scalability:** The paper discusses how power meters can be best installed in large buildings. This approach scales very well to large buildings, as it was especially designed for that goal.
- **Dynamicity & Adaptability:** The configurations have to be reconstructed for every new installation.

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