



Description of EU Projects
Demonstrate Self-Adaptive CPSs
(V1.0)
Systematic Project Review Results

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VICINITY:

Open virtual neighbourhood network to connect intelligent buildings and smart objects [1], [2]
 Website: <http://vicinity2020.eu/vicinity/>

The project presents a standard independent user-centric platform that provides interoperability between different IoT platforms in different domains. It allows users of these domains to share information and to the system to make better decisions in decentralized way. This is achieved by using a concept of virtual neighborhood network.

The proposed architecture consists of VICINITY Cloud and set of VICINITY Nodes to communicate the IoT platforms together (i.e. secure P2P communication), which are define as following:

- VICINITY Cloud: It provides connection to the VICINITY, access control to IoT objects, handles registering and discovery of services, in addition to deploying value-added services (i.e. virtual neighborhood).
- VICINITY Node: integrates value-added services and includes: communication node, gateway API, and adapters & agents.

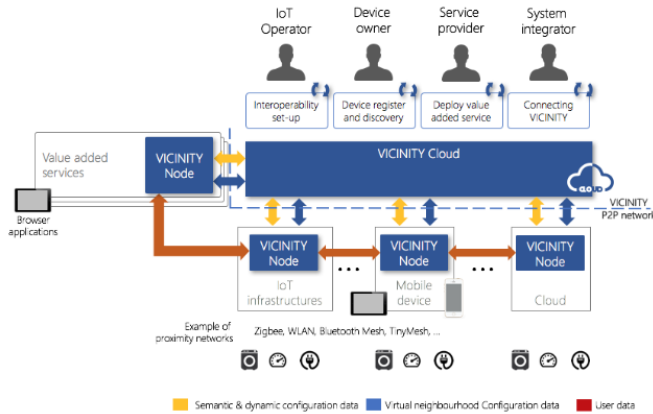


Figure 1 High-level logical VICINITY architecture

The use cases that the project presents target Smart Homes and Buildings, Smart Traffic and Transport, and Smart Grid and Energy. The project runs three related pilots with a mix of these domains, which are presented as following:

Demo1.1 use cases are related to Multiuser Science park, which is in Oslo, Norway. The goal of the pilot is to demonstrate the efficient management of resources in a neighborhood, which involves: environment efficiency, energy efficiency, and water consumption services. More specifically, it provides a virtual neighborhood of buildings integrated in a smart grid energy ecosystem that concerns about controlling smart devices and managing loads of energy consumption, and for intelligent parking space that concerns the process of booking charging points in parking space.

Moreover, the environment efficiency management requires monitoring of rooms conditions from temperature, humidity, luminance, CO2, and occupancy. Whilst, managing energy efficiently, which is related to booking parking/charging services in the building, requires energy consumption profiles to predict the energy demand. Similarly, water efficiency management needs water consumption profiles of residents.

Demo 1.2 use cases are related to Mobility and Building, which is located in Tromso, Norway. The goal of this pilot

demonstrate a neighborhood with high traffic load that requires managing of transport and buildings information to coordinate between the possible customers and the residents and predict their needs.

More specifically, the monitoring involves many sensors such as cameras, screen, light sensor, and parking sensors. After booking, these sensors make sure that the approaching vehicle is authorized, show it the way to the parking place, and detect if the vehicle is occupying the parking place.

As a result, the system has to control: 1) booking and payments, 2) recognition of vehicle, 3) door opening, and 4) detecting delays.

Demo 2 use cases are related to energy ecosystem, which is located in Martin Longo, Portugal. The goal of this pilot is to demonstrate managing energy efficiency. It takes into account the available distributed flexible energy resources and environment quality. Furthermore, the infrastructure should be able to handle value-added services (i.e. service that are not core services) and the monitored data should not contain any private data and it should be exchanged securely. Thus, the monitored areas are municipal buildings with distributed energy sources that have swimming pool, school and nursing home. Hence, the monitored information are temperature, humidity, luminance, CO2, wind, noise, energy production/consumption, and sun radiation that is provided by a smart energy from net-zero energy building (NZEB) unit. It is located on SolarLab and considered as value-added service.

Furthermore, the smart devices control: 1) humidity and temperature in the swimming pool, 2) water pressure in buildings, 3) solar and thermal energy generation for buildings, and 4) air conditioning for school.

Here, we list the challenges under each domain alone. In the case of parts related to Smart Homes and Buildings, the challenges are under performance, price, and cooperation groups. The performance is the challenge of managing resources efficiently. Mainly, it must deal with demand peaks, water leaks, and other non-typical situations. The proposed solution is use prediction of energy consumption and weather forecasting. Regarding the price, the challenge is to have less energy cost especially during the peak times. The solution is to have dynamic pricing with the contribution of prosumers' offers.

In the case of parts related to Smart Traffic and Transport domain, the challenges are under performance, price and cooperation. The performance here is the challenge of managing parking places during traffic peaks. The solution is in providing the private parking places of building for sharing during their availability. The price here is the same challenge of having dynamic pricing for parking places.

In case of Smart Grid and Energy the challenges are under performance and cooperation. The performance here is the challenge of energy management but with considering occupants comfort. Therefore, the suggested solution is to infer the comfort level of occupants and alarm them otherwise.

The cooperation for all three domains is the same challenge of having interoperation between different IoT platforms to exchange information. This is provided by VICINITY architecture.

symbIoTe :

Symbiosis of smart objects across IoT environments [3], [4]

Website: <https://www.symbiote-h2020.eu/>

The project aims at presenting a unified view of different IoT platforms. It can interoperate with each other in a secure way. The goal is to provide services for various smart environments, which contains sensors and actuators. Furthermore, these services are made available for end-users through mobile applications or web applications that are adaptive to the smart environment.

The proposed architecture contains: Application domain (APP), Cloud domain (CLD), Smart Spaces domain (SSP), and Device domain (SD). This architecture provides a secure federation of IoT platforms over cloud. Yet, there are many challenges such as providing a unified way of discovering services, migrating services, roaming devices or reconfiguration of devices. The platform process the request on three levels: fully local-based, hybrid local/cloud based, and fully cloud-based.

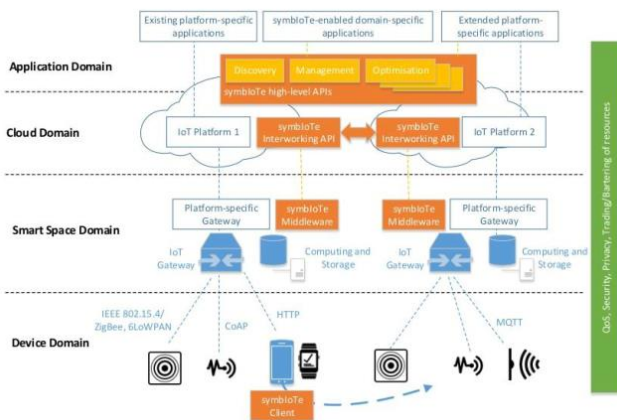


Figure 2 symbIoTe domains

Hence, the project presents three selected use cases as following: two of them are from Smart Homes and Buildings domain and one from Smart Traffic and Transport domain. The first use case is about smart residence that has awareness about energy and healthcare, which is manifested through the following applications:

1) *smart healthy indoor air* (i.e. IoT platform: openUwedat, nAssist) that is responsible of monitoring the air pressure and quality to ensure a healthy residence. For that, the application collects data about the indoor and outdoor environment (e.g. CO₂ levels, temperature, noise levels, etc.) and symbIoTe evaluates the situation and gives recommendations. It is worth mentioning that the outdoor data are collected from various spatial points around the smart residency to enhance the accuracy of estimated values.

2) *smart area controller* (i.e. IoT platform: Symphony, NN platform) that is an adaptable application depending on the smart environment around. So, the application filters out the devices depending on the specific area that user would like to control.

3) *home comfort* (i.e. the IoT platform: Symphony, NN platform) that controls the home devices automatically. Of course, the configuration of devices, which is related to their

locations, is done by an admin. Whilst, the comfort-set points are determined by the resident himself.

4) *Smart Health Mirror SMILA* (i.e. IoT platform: KIOLA) that monitors and displays the information about the user's health, which is collected from his wearable sensors.

The second use case is about Smart Mobility and Ecological Routing, which concerns about finding the best ecological routes. Additionally, it considers the other factors such as available parking, noise levels or traffic in the aim of avoiding health problems. SymbIoTe collects information from different IoT platforms that exist in the cloud and involve wearable and stationary sensors to classify the routes. This services are reachable using two applications:

5) *mobile app* (i.e. IoT platform: OpenIoT, openUwedat, MoBaaS), which allows the user to search for point of interest (POI) or choose a route depending on the environmental state of the street segments.

6) *web app* (i.e. IoT platform: OpenIoT, openUwedat), which recommends a route taking into account the specified preferences entered by the user. Moreover, the application depends on interpolated data from mobile sensors and web as a way to deal with insufficient measurement.

The third use case is about Smart Yachting, which we consider it as smart traffic and transport. The yacht IoT platform interoperates with the port IoT platform through symbIoTe to help in reducing the bureaucracy of berthing process with preserving authority and to suggest needed supply or maintenance tasks depending on the yacht state. It has two applications:

7) *Portnet* (i.e. IoT platform: Navigo Digitale, Symphony), which helps in communicating with port personnel automatically and send them the yacht information (e.g. fuel consumption, latest routes, etc.). This application simplifies the berthing procedure and detects when the yacht arrives to pier.

8) *Centrale Acquisti* (i.e. IoT platform: Navigo Digitale, Symphony), which detects the needs on the yacht since it has access to the resources (e.g. fuel tanks, water tanks). The application sends automatically a request to business application on port IoT platform for offers related to the detected needs and return them to the yachtmen.

In case of Smart Homes and Buildings (i.e. the first use case), the tackled challenge is under performance and resilience groups. The performance is the challenge of saving energy by knowing the occupancy of the room. The solution is to localize the occupants and switch off the devices when the room is empty. Further, the resilience is the challenge of dealing with noise and failures during energy management. The suggested solution is to improve the accuracy by getting more measurements, and dynamically use other resources in case of failures or send alarms.

In case of Smart Traffic and Transport the tackled challenges are under security and resilience. The security here is the challenge of managing the authorization with considering the context. The proposed solution is to use attribute-based control access. Hence, the resilience here is the challenge of having missing information, which could cause failures. Therefore, the proposed solution is to use interpolation to get the missing data.

CADDY:

Cognitive autonomous diving buddy [5]

Website: <http://caddy-fp7.eu/>

The project aims at helping divers in working, orientation and ensuring the diver safety. To do so, the diver's physical state and behavior should be taken into account, in addition to the environmental conditions.

The idea is to have cooperation between surface robot, underwater vehicle, and diver. The surface buddy vehicle is autonomous and used for monitoring mostly. While, the underwater vehicle is autonomous and used for helping the diver in his mission. This structure is used to accomplish the following tasks: "seeing the diver", "understanding the diver", and "diver-robot cooperation and control".



Figure 3 CADDY concept

The use case that the project presents targets Robotics domain in which a human diver is accompanied by robots. This robotic system is able to learn, act autonomously, and adapt to diver's behavior. Hence, the challenge is to help divers by monitoring and assist them in dealing with unexpected failures and to guide them.

The demonstrator includes many experiments such as the following: dive observer, dive slave, dive guide, and diver safety and ergonomics. More specifically:

- Dive guide (i.e. autonomous surface vehicle) helps in guiding the diver through the search path and learns diver behavior. The data is obtained from DiverNet sensor and real-time point cloud. The problems that encounter this experiment is related to imperfection of navigation and technical issues.
- Dive observer helps in monitoring the diver position, maintain the distance and deal with the environmental changes. Thus, the BUDDY detects the diver state (i.e. detect heart rate or breathing rate), and his position with taking into account the difficulties in the environment (e.g. gesture interpretation, darkness). The problems that this experiment encounters are: 1) understanding the gestures, and 2) the visibility of the used gloves that depends on sunlight and gloves thickness.

- Dive slave (i.e. autonomous underwater vehicle) help in following the commands from the diver such as taking pictures or moving object to the surface. The commands are given using hand gestures, which its interpretation could be affected by the light in the area.
- Diver safety and ergonomics helps in evaluating the diver-BUDDY cooperation. It evaluates the preservation of diver safety and the efficiency of the cooperation.

In this use case the targeted challenges are under resilience, cooperation and safety groups. The resilience here is tackling the challenge of overcoming failures of gesture recognition by using Markov process. To overcome the issue, there is no need for collective behavior.

The cooperation here aims at guiding and helping diver by using the autonomous surface/underwater vehicles. It requires monitoring and maintain communication. Thus, improved ultra-short baseline (USBL) positioning algorithms and GPS are used. The improved USBL system enhances the usual positioning algorithm that uses multipath profile. This is done by depending mainly on the first acoustic signal as the most accurate one.

As for safety, the challenge is to monitor the health of human by using net of sensors. The basic issue is to relate raw data and human information to the risks on health. For instance, recognize risks of heart attack from heart rate and age information. The proposed solution is to use fuzzy logic.

OrPHEuS:

Optimising Hybrid Energy grids for smart cities [6], [7]

Website: <http://www.orpheus-project.eu/>

The project presents collaborative hybrid-grid control strategies to minimize the waste in photovoltaic (PV) electricity production. The proposed solution considers new control strategies to transform overproduced electricity to energy for heating water or surfaces.

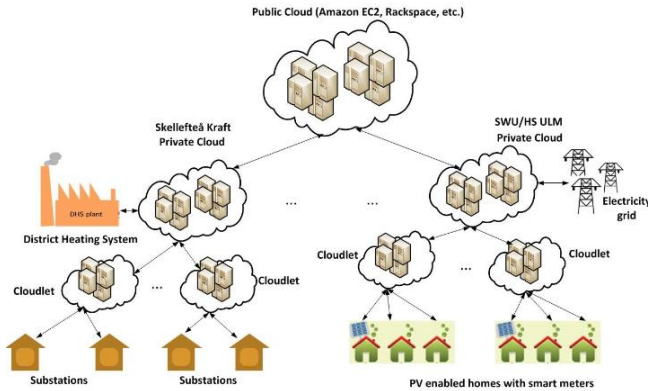


Figure 4 An example cloud-based architecture for smart district heating and electricity grids

The proposed architecture uses co-simulation to link between different physical models. The linking is done by using Functional-Mockup (FMU). The goal is to analysis systems with new proposed control strategies. Moreover, the new control strategies have a big number of input data that is processed and transmitted. Thus, it is necessary to reduce the number of the needed ground sensors with reserving a good accuracy. The presented solution is to collect data from sensors, satellites and weather predictions.

Furthermore, the new control strategies propose both decentralized and centralized control. The decentralized control is used in cases such as using electrical boiler when photovoltaic production was more than consumption. While centralized control is used in cases such as dealing with voltage violation from the grid by switching on devices.

The use case that the project presents targets Smart Grids and Energy domain. It illustrates optimizing of hybrid energy grids use in two locations Skellefteå, Sweden and Ulm, Germany. This is done by new cooperative control strategies. The challenge is to lower the CO₂ and cost of energy using and decreases its waste. For instance, in a solar/photovoltaic system, it is not possible to transmit solar energy from low-voltage to medium voltage grid. Therefore, a lot of produced energy is not used and gets lost. As a consequence, it causes overvoltage in case of high production with low demand of energy. The solution here requires dealing with hybrid energy grids and strategies to distribute the energy.

The demonstrator in Ulm, Germany introduces dealing with the peak of production in neighborhood in a collaborative manner. The scenario contains electric boilers and heat storages, which are used to store the energy. Nevertheless, in case the hot water demand does not use all the PV overproduction in the neighborhood then the energy could be spent on surface heating or domestic hot water. In this way, fossil fuels usage is reduced, maximum of the PV production electricity is used, and minimum global cost is achieved. It is worth mentioning that the control could be centralized or decentralized.

Another case in Skellefteå, Sweden, which introduces a combined-heat-and-power (CHP) plant. The CHP produces both heat and electricity from biomass. So, the scenario involves biomass boilers and oil boilers. The oil boilers are usually used for heating in winter, but they are expensive to run and maintain in addition to their CO₂ emission. Therefore, CHP plant is used to provide electricity during the peak of oil boilers in a flexible way. The alternative energy is generated from biomass boilers and wind farms. Using those energy generators reduce CO₂ emissions and costs.

In this use case the targeted challenges are under performance and price groups. The performance is the challenge of managing energy efficiently. This challenge requires dealing with delays in offloading and predict demand and environment. Additionally, it uses cooperative control strategies to handle both PV surplus and overvoltage in the grid.

The price is provided by replacing the oil boilers with less expensive producers such as biomass boilers, and transfer the electricity overproduction to another form such as water heating.

ClouT:

ClouT: Cloud of Things for empowering the citizen clout in smart cities [8], [9]
 Website: <http://clout-project.eu/>

The project introduces a dynamic storage of historical data on cloud that allows users to share services. Since the size of stored data from city IoT is unpredictable and huge. Thus, elastic and scalable clusters are required. Hence, sharing resources with many users at the same time may cause conflicts, which this project aims to deal with.

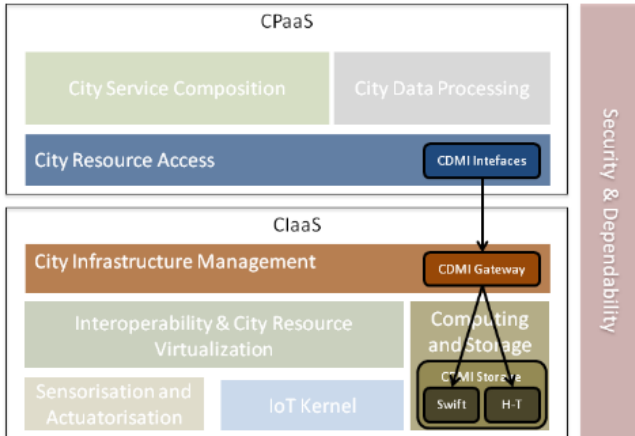


Figure 5 Cloud storage in ClouT architecture

The architecture provides City Infrastructure as a Service (ClaaS), City Platform as a Service (CPaaS), and City Software as a Service (CSaaS).

The storage process starts with gathering information from various city devices (e.g. sensitized, virtual, ... etc.). The data is gathered through heterogonous communication interfaces, and then it is stored.

In other words, data from sensors are stored in cloud using SensiNact Gateway, which consists of northbound and southbound adaptation bridges. After that, SeniNact IoT Gateway uses Cloud Data Management Interface (CDMI) to deal with data. It is divided to: 1) CDMI interfaces for accessing the storage and managing the historical data, 2) CDMI Gateway that categorizes data, 3) CDMI storage component that manifest elasticity using OpenStack Swift and Hypertable. Finally, the dashboards calculate index of interest from stores data for the evaluation (e.g. weather index, dry index... etc.).

The use case is a Cloud domain. It provides a dashboard for citizens and municipalities to access or provide different information. For instance, municipalities provide data about the city such as traffic. Also, they can contribute in enhancing their city by giving feedbacks (e.g. opinion about a restaurant).

The use case presents IoT with people, which is introduced by a competition between four cities: Fujisawa, Genova, Mitaka, and Santander. Each city has a set of services in the cloud allowing people to add and share their own services. The challenge is to resolve the conflicts between the users' activities.

More specifically, the services in the cities are as following:

- In Fujisawa city, the sensed data is about environment, pollution, traffic, and river conditions. Additionally, the use case there involves collecting

data from citizens about waste to collect and send it to garbage cars.

- In Genova city, the sensed data is about environment, pollution, and public transport. The proposed cloud services improved the life in the city by increasing safety and response speed (i.e. faster communication).
- In Mitaka city, the sensed data is about environment, pollution, traffic, and bikes. The services there propose to advertise the city in different aspects such as citizens sharing interesting roads to walk or pictures about the city.
- In Santander city, the sensed data is about environment, pollution, traffic, public transport, bikes, and participatory sensing. The services allow citizens to give feedback about the city using smiley (i.e. smiley recognition on dashboard).

As a result, the user of this architecture can share services from different cities.

In this use case, the challenges are under resilience and sharing services groups. The resilience here is the challenge of self-healing and load balancing. The self-healing is tackled by classifying and learning faults, while load balancing is tackled by having scalable and elastic cloud to store data.

Secondly, the services sharing is provided by using a cloud which stores data from heterogeneous communication interfaces and provide services from different cities.

RECONFIG:

Cognitive, Decentralized Coordination of Heterogeneous Multi-Robot Systems via Reconfigurable Task Planning [10], [11]
 Website: <http://www.reconfig.eu/>

The project focuses on formal method-based planning for collaborative grasping and carrying objects by robots. The objectives of the projects are to improving dealing with visual information, robot-to-robot gesturing detecting, point-to-point navigation, localization, stable grasp, and collaborative picking and carrying.

The proposed architecture is distributed since the communication between robots is local. Hence, robots form their knowledge about the surrounding, which is partially known, by their own sensing in addition to exchanging knowledge with each other. This knowledge is used by Behavioral Trees (BT), which control the robot in planning and rectifying the motion. Moreover, multi-robot BT improved performance by parallelizing actions and fault tolerance by having fallbacks, besides the tasks satisfaction verification on runtime.

The architecture target developing the following points:

- Realizing the surrounding by processing visual data.
- Implicit/Explicit Communication between robots.
- Navigation.
- Planning.

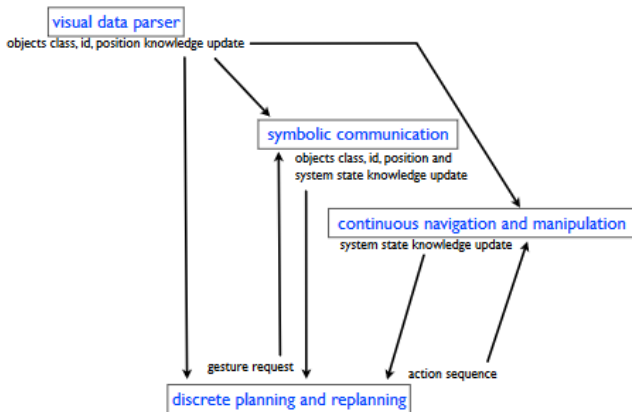


Figure 6 System architecture outline diagram

The agents target satisfaction of individual goals instead of centralized processing for team goals. The trick is in continuous synchronization of behavior and re-planning. This provides a way to avoid big transition states caused by product automata of all agents. The point is that the representation of agent behavior is individual and for multi-agents is with short horizon instead of infinite horizon. That makes the complexity less and checks the team goal satisfaction bottom-up by satisfying individual tasks.

The use case that the project presents targets Robotics domain in which there are cooperative robots that target achieving a shared goal. The demonstrator has an observer, a NAO robot, and three wooden cars. So, the focus is on: pointing gesture, and having manipulative situation.

The first part of the experiment (i.e. pointing gesture) involves NAO robot that is planned to be in 11 positions and points 10 times on the wooden cars in fixed locations. The detection here uses probabilistic approach, which returns

better results since it deals with ambiguous situations. It is worth mentioning that the robot was trained on noisy images. Afterwards, a new object was added with different locations (i.e. a manipulative situation) and fixes observer. This results of new workspace model, plan and check for task satisfaction. Regarding achieving goals, the used decentralized planning framework considers local and global goals (i.e. tackled by a group of collaborative robots) in which the agents themselves compute the local goals. So, each robot has each has local goals, but they collaborate in carrying an object (i.e. the collaborative movement is leader-follower scheme). The demonstrator tackled the challenge of having the communication implicit rather than explicit, which are defined as following: implicit communication is done through force sensing and keeping trajectory profile, while explicit communication is done through messaging between robots. The results showed that the implicit method was more efficient than the explicit.

This demonstrator could be used in a use cases such as spotting chairs in one room and move them to another, where the targeted challenge lies in having manipulative situations instead of predefined ones (e.g. spotting a new chair). Additionally, the robots are able to cooperate in decentralized way to achieve global goal with taking into account communication limitations/constraints.

In this case the challenges are under safety, resilience, cooperation, and connectivity groups. The safety is the challenge of avoiding collisions by using constraint based solving. Whilst, the resilience is the challenge of overcome noise movement detection by training the robots on noisy images. Regarding the cooperation, the challenge is in recognizing the gestures, planning and localizing. Therefore, the proposed solution is to use statistics, classification and machine learning to deal with ambiguity, and probability for optimizing the location. Finally, the connectivity is the challenge of depending on implicit communication to minimize the info exchange. The project proposes having a trajectory profile of robots movement instead of position and velocity information, which minimize the computation and make it more accurate.

HYDROBIONETS:

Autonomous Control of Large-scale Water Treatment Plants based on Self-Organized Wireless BioMEM Sensor and Actuator Networks [12], [13]
 Website: <http://www.hydrobionets.eu/>

The project aims at developing Wireless BioMEM Networks (WBNs), which have microbiological-awareness, are used for distributing monitoring of the water treatment and desalination process in a large-scale industry to improve the productivity.

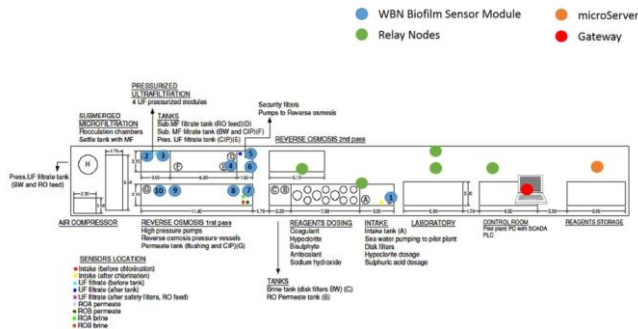


Figure 7 HBN Platform Component in pilot plant layout

The represented distribution of plant components and sensors are in Figure 7. The main parts in WBNs are:

- WBN Biofilm Sensor Module, which receives and processes commands related to collecting data, and biofilm sensor sampling.
- Relay Nodes, which is responsible for connectivity between all the components in the plant (i.e. the WBN nodes and the microServer).

In the system, the collected information is related to the plant and the network. Where in case of plant, the data from HYDROBIONETS sensors and biofilm sensors are correlated to get the interrelations between biofilms growing and other environmental factors. The network data (e.g. transmission and reception rates) is used by Network Management Layer in such cases as monitoring, adapting and failure management.

For example, the network connectivity depends on 1-hop only to connect with other nodes. This makes the options limited and challenging to reach the microServer due to the packet loss and impact of biofilms over sensors and their measurements. Therefore, HYDROBIONETS control is used to improve the productivity instead of using traditional methods that slow down the filtration.

The problems in sensing are 1) the time of measuring of each sensor is different, which requires more measurements to increase the accuracy, and 2) the missing information during sampling periods in a case of malfunction for instance, which requires matrix completion or just a longer acquisition time periods (i.e. better time scale or data accuracy).

It is worth mentioning that not only does WBNs consist of sensors, it also includes materials, microsystems, communications, signal processing, control and networking experts, and end-users.

The use case that the project presents is a “La Tordera” desalination pilot plant. It falls in a Smart Factory and Manufacturing domain. It illustrates large-scale Self-Organized Wireless BioMEM Networks (WBNs) is “La Tordera” desalination pilot plant, which includes wireless sensors network to monitor parameters (e.g. water pollution)

and control the amount of chlorine and biocide that are added to water during its treatment stages.

The system has seawater as an input, which is filtered using disk filters. Then, it goes through two stages of pretreatment to clean the water from unwanted particles or smells, and finally it goes to the reverse osmosis system. There are measurement sensors before and after each step in the process.

The nodes work on battery with short communication range and distributed managing. The system considers uncertainty in sensor data and network problems as collisions of sent packets over the network. The aim is to prevent bacteria biofilm formation in the membranes (i.e. a slippery layer of bacteria on the ultrafiltration texture), improve performance, and decrease energy use.

In this case the challenges are under performance, resilience and connectivity. The performance here is the challenge of saving resources by using the right frequency and duration for the desalination process that depends on water nature. Additionally, the energy of cleaning the membranes could be saved by avoiding biofouling. The proposed solution is using specialized sensors for monitoring. The resilience is the challenge of dealing with missing information and noise in measurements. The proposed solution is to use interpolation, matrix completion and subspace projection. Additionally, the system deals with abnormal behavior by deactivating the problematic sensor. Regarding the connectivity, the challenge is in having noise, delays, and dealing with node failures. The proposed solution is to get more measurements, downsampling, and prediction respectively.

INERTIA:

Integrating Active, Flexible and Responsive Tertiary Prosumers into a Smart Distribution Grid [14]
 Website: <http://www.inertia-project.eu/inertia/>

The project presents a system to manage efficiency of energy smart grids. It takes into account user comfort and provides dynamic pricing that minimizes expenses.

The INERTIA architecture proposes three basic levels to manage energy:

- Distribution System Operator (DSO) Control Hub, which communicates with aggregator control hub.
- Aggregator Control Hub, which is responsible for managing the daily needs of aggregators between customers and stakeholders.
- Local Control Hub, which is responsible for collected and predicting local data.

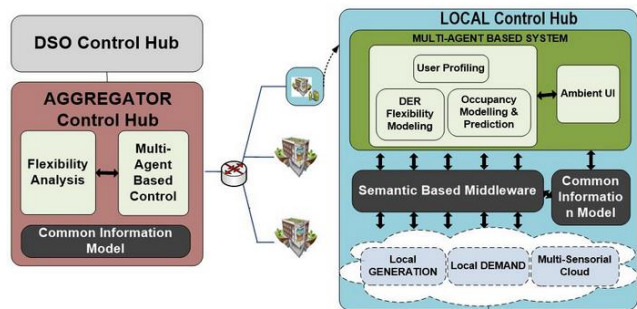


Figure 8 INERTIA high-level system architecture

More specifically, DSO Control Hub is responsible for dealing with distributed Medium Voltage Control Center. The aim is to manage power flows situations such as peak loads, and keep the grid node voltage in allowed limits.

For Aggregator Control Hub, it ensures the flexibility in managing the electricity of prosumers that requires distributed energy resource (DER) utilization. Whilst, the multi agent based control is responsible for coordinator between agents that controls when to cooperate and when to compete. Also, it helps in determining which operations will be sent to the local control hub in the aim of optimizing performance. The common information model represents the existing information elements that are exchanged.

Regarding the local control hub, it has:

- 1) multi-agent based system that consists of user interface, user profiling, DER flexibility and occupancy modeling & prediction.
- 2) semantic based middleware with common information model.
- 3) local demand and generation in addition to multi-sensorial cloud.

In the first part, it stores data about users that provides behavioral patterns to infer their preferences in different domains and spaces. The aim is to use the results in prediction. Additionally, it considers the environmental and physical parameters related to energy consumption and generation. So, the information and its analysis is accessible by the user interface. The second part is a middleware that provides heterogeneous devices to access the data and work together. Finally, the third part is the part that analyze the collected data.

The use case is from Smart Grid and Energy domain, which targets having interoperability between the presented

framework and real devices. The basic focus is on performance, load distribution, and demand response strategies. The pilot contains three buildings of CERTH, where sensors and actuators are distributed (e.g. sensors for measuring temperature, energy consumption, occupancy, light actuators ... etc.). Moreover, prosumers are able to generate energy locally besides their consumption. In case of buildings, the local demand is influenced by environmental changes and occupancy, while the local generation is provided from distributed PV park. The PV park is able to cover the local demand and feedback the rest to DSO and the aggregator. It is worth mentioning that the local generation depends on the environmental conditions such as night or a cloudy day.

There are three basic points that the pilot highlights, which are:

- 1) *utilizing prosumer flexibility with various control strategies:* Managing the occupants behavior and preferences in addition to considering financial profits.
- 2) *offering ancillary services to system operators:* Adding flexibility to deal with network congestion after a fault and avoid voltage limits violations.
- 3) *utilizing portfolio flexibility for imbalance risk reduction services:* prevent overload and overvoltage with engaging the Aggregator.

In this case the challenges are under performance and cooperation groups. The performance here is the challenge of supporting flexibility in energy use that the system can handle demand peaks and changes in context. Therefore, the suggested solution is to use classification, trend, and outliers analysis for energy demand response. Additionally, the project proposes prediction for occupancy. Regarding the cooperation, it is also tackling the challenge of having flexibility, but the point is to have different degrees of flexibilities of demand response models. This is done by using multidimensional analysis and correlation. In other words, it provides interoperation between consumers and prosumers to handle the demand response model.

NIFTi:

Natural human-robot cooperation in dynamic environments [15]

Website: <http://www.nifti.eu/>

The project targets cooperation between human and robots to rescue people. Urban Search and Rescue (USAR) involves Human-robot interaction (HRI) by spoken dialog or graphical user interface (GUI).

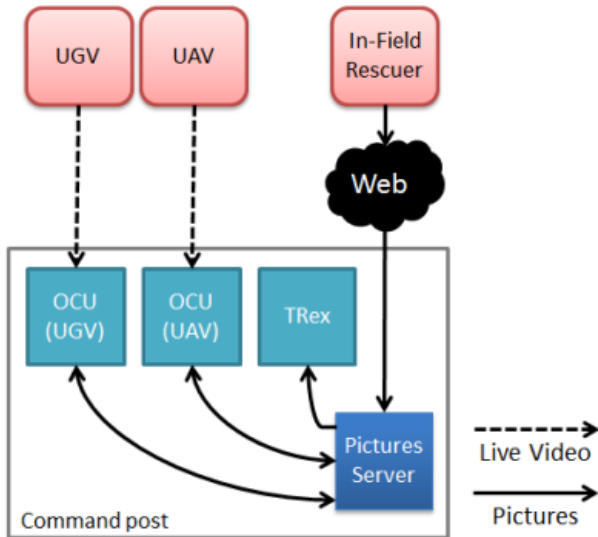


Figure 9 The system architecture with the In-Field Pictures Server

The proposed architecture consists of team members, shared space, Operator Control Unit (OCU), and TRex. More specifically, the team members are:

- Unmanned Aerial Vehicles (UAV): It is a micro-copter with two cameras to send video snapshots, and controlled by trained pilot.
- Unmanned Ground Vehicles (UGV): It is semi-autonomous ground robot. It has two adaptable tracks on each side with flippers, camera and rotating laser. The semi-autonomy was introduced instead of high level of autonomy, because of the trust issues from human side in the robot during difficult situations. Nevertheless, the autonomy is considered good in case of high cognitive load.
- In-Field rescuer: He is a team member who sends pictures taken by an internet-enabled high-zoom digital camera.

As for the Operator Control Unit (OCU), it accepts voice and touch as inputs. It has the output as displaying videos and maps of the environment with the robots and obstacles. Finally, the TRex is responsible for the tactical planning of the robots.

The team, which contains both robots and humans, should be able to communicate about the situation and share information by dialogue or virtual (i.e. pictures or videos). To make the collected data reachable by team members, the project proposed a shared space. In other words, the saved In-Field pictures and videos are proposed for remote access (i.e. Dropbox on an In-Field Server/cloud provider). Of course, some additional information is possible to add to the pictures. This way is used to avoid losing information during speaking such as textual description, geo-localization, direction ... etc.

Afterwards, the information is broadcast through NIFTi network, which has two ROS nodes with UGV and UAV.

Finally, TREx manages the tactical information from the collected data. It shows the plans for the rescue mission on a map, and ensures that they are collision free. It is worth mentioning that the central decision making is minimized by determining “what to do” instead of “how to do it”.

The use case is from Crisis and Emergency domain. It targets exploring and rescuing missions in case of disaster such as earthquake. Furthermore, the rescue team involves humans and robots working together. Therefore, the robots must be cognitive and situation-aware to be able to achieve shared goals by human-to-robot communication.

The experiment is done in a tunnel in Prato, Italy. It involved two robots that send pictures to a server in the aim of sharing the information with the rescuer. In addition, the robots can detect cars and victims, and alert rescuer.

Although robots follow the predefined plan from the rescuer, but they are still able to plan and utilize the resources. More specifically, the map is situation-aware. Thus, the rescuer can see the obstacles and change the path for the robot on 3D map using a pen. These changes generate a sequence of events for the UGV to follow.

Another way to communicate between human and robot is by vocal commands. To handle these commands, cognition is used. It is improved by considering differentiating between acoustic correlation of physical stress and cognitive load by studying the features of both. The first one had clear features, while the second one needed linguistic features to improve the classification of the features.

In this use case the challenges are under resilience and cooperation groups. The resilience here is the challenge of localization with noisy data. The proposed solution is a robust data fusion that also uses filters and prediction. Whilst, the cooperation is the challenge of recognizing if the rescuers are mentally overloaded, in addition to adapting to limitations of transmission bandwidth. Therefore, the solution is to use classifier for recognizing the stress level, and filtering and downsampling for the transmission boundaries.

GreenCom:

MyGrid; Energy Efficient and Interoperable Smart Energy Systems for Local Communities [16], [17]
 Website: <http://www.greencom-project.eu/>

The project presents a use case related to Smart Grids and Energy. It ensures the comfort of the users on one hand, and saves energy consumption on the other. This is done by monitoring and supporting decision making of customers. Hence, the targeted challenge is in having an efficient energy management that enhances performance while preserving security.

The use case includes company employees who want to monitor consumption and flexibility of the devices in the company. Also, it involves prosumers at home who want to monitor their own consumption.

In this use case, the challenges are under resilience, performance, price and security groups. The resilience here is the challenge of adding flexibility in dealing with energy demands. This is done by using microgrids and prosumers. Additionally, it requires having context awareness. In other words, the system needs to synthesis patterns in context, and use those pattern for prediction of the energy consumption.

The performance here is the challenge of providing scalability to the system. For instance, the system is able to add big numbers of sensors by having hierarchal structure. Also, the system uses caching for improving the throughputs of flexibility profiles. Therefore, it requires only updating of new parts in it. The price here is the challenge of having dynamic cost for the energy. Finally, the security here is the challenge of authentication with clear policy access. This is done by using role-based access control instead of the usual simple authentications.

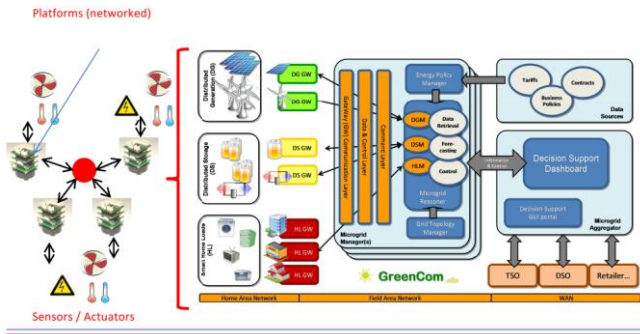


Figure 10 Sensors / Actuators within the GreenCom Framework

The provided architecture considers the following parts:

- Collection of data: The data is gathered from appliances, smart home devices, heat pump, sensors and actuators. Hence, the heterogeneity of the sensors is solved by using LinkSmart middleware. It provides a direct support for the sensors or proposes virtualization. It is worth mentioning that not only does the collected data contain sensors data, but it also has alarms, network and device status.
- Gateways: They have two roles, which are related to collected data and communication/configuration of components. The gateways are connected to sensors and devices via wireless/wired connection. They are responsible for getting the collected data and transfer it to the Home Load Manager using internet connection.
- Home Load Manager (HLM): It helps in optimizing and stabilizing the grid production in a secure way by using microgrids. Hence, microgrids mainly have managers and aggregators. MicroGrid Manager (MGM) is responsible for storing and processing the collected data sent from gateways. Additionally, it predicts load in the aim of reducing peak load and optimize the cost. Whilst, microgrid aggregator connects the information from different microgrid managers to support decisions.

The architecture provides means to detect warning situations, do a short-term forecast, and control the flexibility of devices or aggregators. In case the internet is not available the data is stored locally. Then, the data is sent when the connection is established again.

The project pilot targets Smart Grids and Energy domain. It presents Home Monitoring and Control in addition to Heat as a Service (HMC/HaaS). Thus, the structure proposes having transformer stations that allow many householders to be prosumers. The prosumer has the consumer side that includes appliances and heat pumps, and the producer side that includes photovoltaic panels, local wind turbines, and batteries.

ASCENS:

Autonomic Service-Component Ensembles [18]

Website: <http://www.ascens-ist.eu/>

The project targets designing dynamic systems with collective behavior. The aim of those systems is to make a group able to solve complex problems that an individual is not able to do. Therefore, a methodology that targets emergence behavior engineering is presented. It focuses on self-adaptation and awareness issues in addition to performance.

The project has basic concept of ensembles and they presented with many different tools and approaches. The ensemble is a collection of autonomic components that have a common goal to achieve. The component performs self-adaptation depending on its knowledge by forcing policies. A formal language is defined for this purpose which is called Service Component Ensemble Languages (SCEL). In SCEL, it is possible to define components behavior, and ensembles formations. The components have interfaces that contains attributes or knowledge, and the ensembles perform the knowledge exchange between the components under some constraints. The dynamicity comes from depending on attributes to form the ensembles. Thus, the designed system is context-awareness one.

The project proposes using different tools for modeling and simulating ensembles that aim at achieving individual and global goals. The modeling tools are: SCEL, HELENA, KnowLang, DEECo. The simulation tools are: ARGoS, SPL, jDEECo Java, SimSOTA

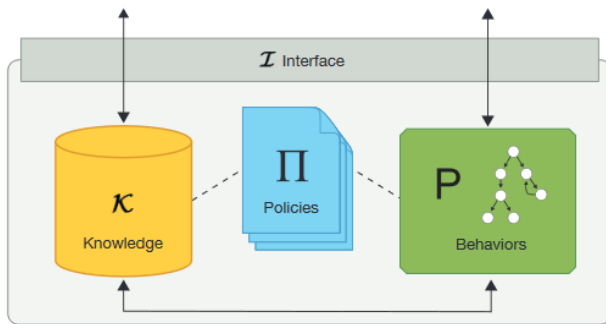


Figure 11 Service Component

The project presents three use cases related to Crisis and Emergency, Clouds, and Smart Traffic and Transport domains. The use cases illustrate the individual and group behavior of autonomous entities in the aim of achieving the requirements.

The first use case is about robot swarms, which is related to Crisis and Emergency domain. Due to the unknown environment in case of a disaster, the robots task is to explore the surroundings and find victims to save. This task could require an interaction between simple robots to accomplish a common goal. Hence, the challenge is to achieve a goal that is not possible to achieve by individual robot, and overcome the failure of individuals in difficult environment. More specifically, the robots can take role of land markers or explorers to construct a map of the surrounding area. What is more, land markers can be temporary, stable or near to victim and acts as a beacon while explorer is in range of a land marker. The other operation that robots target to achieve is to construct a wall where the construction should be in parallel

by dividing the building area into segments. Segments are supervised by robots known as guard robots. They mark the end of a segment, guard robots and allow for only one builder robot at a time. Whereas builder robots looking for objects, approach objects, and grip objects. Consequently, the robots should be aware of individual and ensemble state to achieve the goal.

In this use case the challenges under safety, resilience and cooperation groups. The safety is the challenge of avoiding collisions and obstacles, which formal methods is used as a solution. The resilience is the challenge of being context-aware and overcome failures. The proposed solution is to use ensembles that provide the system with such needed dynamicity. Also, ensembles help in cooperation, where the challenge is to overcome a failure of individual to achieve a common goal.

The second use case is about Science computing where load maintenance in clouds is the target. Yet, the challenge is in having an awareness of changes in load that requires sharing computing resources to ensure resilience, save energy and decrease cost. The idea behind Science computing is to use peer-to-peer computing from volunteers in the aim of having ensembles of cloud components that are dynamic, self-aware, self-monitoring and self-adaptive. Due to the monitored load, the resources could be added/removed dynamically (e.g. run or shutdown a virtual machine).

In this use case the challenges are under performance, price, and resilience groups. The performance is the challenge of managing resources, which is tackled by stopping an idle VM. Also, price is the challenge of minimizing the cost of used resources by stopping the idle services. Regarding the resilience, it is the challenge of dealing with high load and failures. The proposed solution is to add dynamicity using ensembles.

The third use case is about E-mobility, which is Smart Traffic and Transport domain. It demonstrates the vehicle planning for optimal route with consideration of parking/charging availability and driver plans. Hence, the awareness about traffic conditions, energy limitations, and time limitations are involved in the optimization and prediction process in which helps dealing with the challenge of reaching the target considering all the mentioned points.

In this use case the challenge is under performance group. The performance here is the challenge of resources usage that is tackled by optimization, prediction and formal methods.

IPAC:

Integrated Platform for Autonomic Computing [19]

Website: <http://ipac.di.uoa.gr/>

The project presents a platform for building collaborative autonomic embedded systems on mobile nodes. The proposed middleware is used for developing services that are context-aware and uses short-range communication for information exchange (i.e. event-based). Thus, the used information dissemination algorithms are similar to how rumor spreading works.

The main parts in the proposed architecture are:

- Sensing elements component (SEC), which represents the involved heterogenous sensors. The sensors are represented by hierarchical model. To handle heterogeneity, the project proposed a model-driven approach with ontologies.
- Short range communication component (SRCC), which presents the interface for information exchange and reduces latency. Through this component, the nodes could communication using WiseMac or Wi-Fi.
- IPAC core middleware itself, which is a container for the software components that coordinates between the platform parts (i.e. mainly: sensing, reasoning, networking and storage).

The IPAC nodes, which are communication entities (CE), can be relaying nodes (RN) or end nodes (EN). The RN receives the information and spreads it again without processing. The EN processes the information before spreading it again in case it is relevant.

Furthermore, there are many features associated to spreading the relevant information such as how much the content is critical, the time/space validity, network density and node mobility.

Moreover, the nodes have policies that define the adaptation and reconfiguration situations (e.g. change communication interface). More specifically, the policies are formed by knowledge-based reasoning and inferencing over real-time data.

sharp-turned roads, or a vehicle gets off-road. Here, the challenges in this use case are to avoid accidents, collisions, and false alarms. This is achieved by propagating information between vehicles. Therefore, the vehicles detect road state or the distance from other vehicles in the way and propagate the alarms. The aim is to be able to predict the potential risks and choose the best reaction for the situation to prevent accidents. In this use case, the targeted challenges are under safety group. More specifically, the safety challenge here is to avoid accidents and collisions by gathering information/alarms from other vehicles. The proposed solution to overcome the challenge is to disseminate information and alarms between vehicles. This might encounter network problems that is handled by communication reconfiguration. Moreover, the vehicles evaluate the situation locally and verify it using information from other vehicles.

Whilst, Crisis and Emergency use case describes crisis management for natural or human-made disasters (e.g. storms, earthquakes, epidemics spreading, industrial mishaps, ... etc). The challenge here lies in providing a communication infrastructure in the accident place for exchanging information. Thus, IPAC framework provides an infrastructure that allows vehicles and team members to communicate and coordinate.

In this use case, the targeted challenges are under connectivity group. More specifically, the connectivity challenge here is to deal with: 1) end-to-end network problems by communication reconfiguration, and 2) having no network connection by local broadcasting using short-range communication for information exchange.

Finally, Smart Factories and Manufacturing use case targets manufacturing plant control. It also needs a framework to connect the different entities in the industry together. The challenge here is to monitor production process and apply quality control in addition to focus on energy efficiency and managing storage and parking. To achieve that, IPAC is used as a communication infrastructure between different kind of entities in the industry (e.g. control room, assembly-line machines, sensors...etc.).

In this use case, the targeted challenges are performance and cooperation. More specifically, the performance challenge is in achieving energy efficiency, which is tackled by WiseMac protocol with beaconing process. Even though, the protocol uses broadcasting, but it does not require routing. Also, beaconing requires less energy. Regarding the cooperation, this involves monitoring as it is mentioned in the project abstract, but the main challenge here is to localize the nodes in the parking place. This is tackled by using a central mobile node that measures the strength of radio signals of other vehicles in addition to the GPS information.

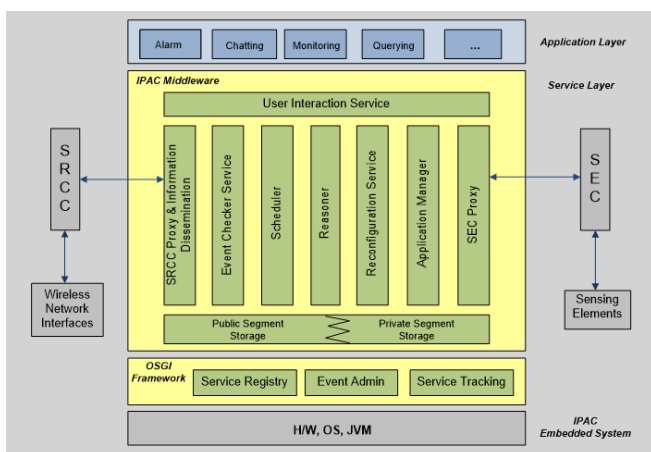


Figure 12: IPAC middleware architecture

The use cases that the project presents target Smart Traffic and Transport, Crisis and Emergency, and Smart Factory and Manufacturing domains.

The Smart Traffic and Transport use case describes a Vehicle Early Warning System (VEWS) that deals with hazardous situations. For instance, vehicle has a poor night vision on

References

- [1] vicinitymanager, "VICINITY | D1.3 Report on Pilot sites and Operational Requirements," *Vicinity*, 23-Oct-2017. [Online]. Available: <http://vicinity2020.eu/vicinity/content/d13-report-pilot-sites-and-operational-requirements>.
- [2] "VICINITY | D1.6 VICINITY Architectural Design." [Online]. Available: http://vicinity2020.eu/vicinity/sites/default/files/documents/vicinity_d1_6_architectural_design_1.0_0.pdf.
- [3] "symbIoTe | D1.3 - Final Specification of Use Cases and Initial Report on Business Models," [Online]. Available: <https://zenodo.org/record/817480#.WsNjyue-nmE>
- [4] "symbIoTe | D5.1 - Implementation Framework," [Online]. Available: <https://zenodo.org/record/817410#.WsNj-ue-nmE>
- [5] "CADDY | D8.3.3 Six-month project report M25-M30," 2016. [Online]. Available: <http://www.caddy-fp7.eu/userfiles/file/Deliverables/M25-M30%20CADDY%20Report.pdf>.
- [6] "OrPHyEuS | D.5.3.2 Recommendations for control strategies on future use cases," [Online]. Available: http://www.orpheus-project.eu/images/pdf/OrPHEuS_D5.3.2.pdf
- [7] "OrPHyEuS | D.7.1.2 Impact of Cooperative Control Strategies for cities' Hybrid Energy Networks on European scale," [Online]. Available: http://www.orpheus-project.eu/images/pdf/OrPHEuS_D7.1.2.pdf
- [8] "ClouT | D3.4 CPaaS specification and reference implementation – final release and feedback after field trials." [Online]. Available: <http://clout-project.eu/documents/deliverables-access/>.
- [9] "ClouT | D4.3 Final report of City Application software, field trials and evaluation results." [Online]. Available: <http://clout-project.eu/documents/deliverables-access/>.
- [10] "RECONFIG | D5.1: Scenario Definition." [Online]. Available: <http://www.reconfig.eu/>.
- [11] "RECONFIG | D5.7: Performance Assessment." [Online]. Available: <http://www.reconfig.eu/>.
- [12] "HYDROBIONETS | D2.1: Scenario descriptions and system requirements (v1)." [Online]. Available: <http://www.hydrobionets.eu/index.php/deliverables>.
- [13] "HYDROBIONETS | D2.2: Scenario descriptions and system requirements (v2)." [Online]. Available: <http://www.hydrobionets.eu/index.php/deliverables>.
- [14] "INERTIA | D6.3 Pilot Results & User Experience Evaluation." [Online]. Available: <http://www.inertia-project.eu/inertia/results/index.html>.
- [15] "NIFTi | DR 3.4.4: Adaptive situated HRI for in-field joint exploration." [Online]. Available: <http://www.nifti.eu/results/pdfs-of-public-year-4-deliverables>.
- [16] "GreenCom | D2.4.1 initial prototype application specification v1.0." [Online]. Available: <http://www.greencom-project.eu/>.
- [17] "GreenCom | D3.1.1 initial system architecture analysis design specification 1.0." [Online]. Available: <http://www.greencom-project.eu/>.
- [18] "ASCENS | D4.4 - Fourth Report on WP4." [Online]. Available: <http://www.ascens-ist.eu/images/ascens/deliverables/year4/d74.pdf>.
- [19] "IPAC | D1.5: Final Project Report," 28-Jul-2011. [Online]. Available: <http://ipac.di.uoa.gr/node/15>.