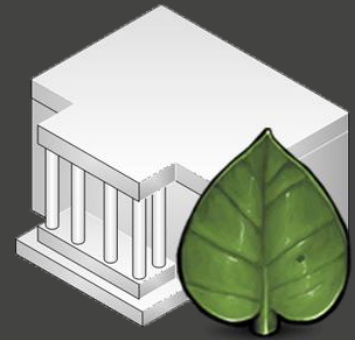


# The Smart IHU Platform



Technology Forum 2015

Research Assistant

Thanos Stavropoulos, MSc

Researchers

Asst. Prof. Dimitris Vrakas, Dr. George Koutitas,

Assoc. Prof. Nick Bassiliades

Coordinator

Prof. Ioannis Vlahavas



INTERNATIONAL  
HELLENIC  
UNIVERSITY

# Overview

- Introduction: Aims, Team, Field
- 1. Devices & Middleware
- 2. Semantics
- 3. Applications
- Conclusions, Dissemination, Publications
- Future Work

# Project Aims

- To thoroughly monitor, administer and reduce the building's energy consumption
- To build a robust, large infrastructure for
  - R & D in Ambient Intelligence, Semantic Web Services, Internet of Things, Smart Grids
  - Dissemination of IHU, R & D during studies
  - Applied R & D in the industry

# Project Information

- Institution
  - School of Science & Technology, International Hellenic University (IHU)
- People Involved
  - 6 researchers
  - 12 BSc & MSc theses students
- Duration
  - Development phase: 2010 – 2013
  - Pilot phase: 2013-now
- Budget
  - ~110.000 €

# Project Team

- Coordinator
  - Prof. Ioannis Vlahavas
- Academic Assistant
  - Dr. George Koutitas
- Researchers
  - Dr. Dimitris Vrakas, Asst. Prof.
  - Dr. Nick Bassiliades, Assoc. Prof.
- Research Assistants
  - Thanos Stavropoulos
  - Dr. Ageliki Trioliaridou
  - Dr. Kalliopi Kravari
- BSc, MSc Students
  - Andrea Dimitri \*
  - Danai Vlachava \*
  - Dimitris Daskopoulos \*
  - Kostas Demiris \*
  - Miliadis Damianidis \*
  - Miltos Nedelkos
  - Stratos Makryiannakis
  - Konstantinos Gottis
  - George Pilikidis
  - Alex Arvanitidis
  - John Argyriou
  - Dimitris Sfounis

\* MSc in ICT Students at the IHU

# Challenges

- Devices
  - Heterogeneous data
  - Platform-dependent
  - Local Access
- Web Service Integration
  - Syntactic & Semantic Interoperability
- Applications
  - Platform-independence
  - Universal, Remote Access
  - Algorithms, Planning, Rules, Agents

**Devices**  
*Various Platforms, Protocols*

**Middleware**  
*Exposes Data & Semantics*

**Intelligent Applications**

# Novelty

## Middleware

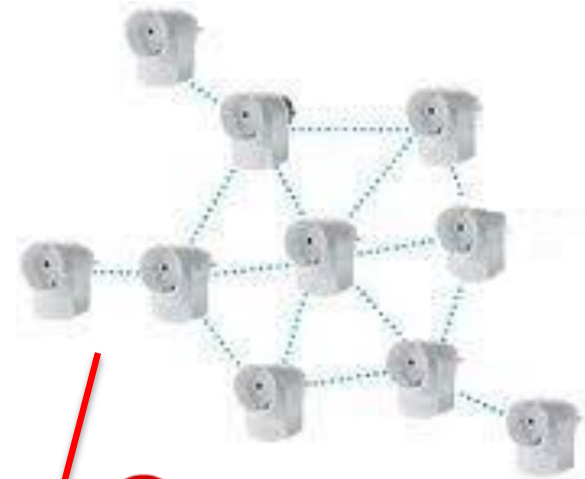
- ✓ Integrate & repurpose unique devices (retail)
- ✓ Robustness for a large-scale deployment

## Semantics

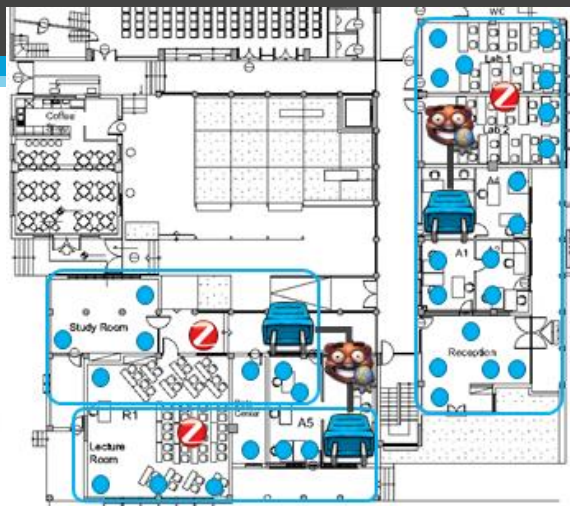
- ✓ Annotation & Discovery infrastructure

## Intelligent Applications

- ✓ Aml application in energy
- ✓ Real-world piloting and actual energy savings







- 43 Smart Plugs (3 nets)
- 20 Sensor Boards (2 nets)
- 7 Smart Clampers (2 nets)
- 1 Z-Wave net
  - 3 Smoke Det.
  - 11 Motion IR
  - 4 CO<sub>2</sub> Level



Smart Plug Coordinator



Sensor Board Gateway



Smart Clamper Coordinator



Z-Wave Controller



aWESoME Server

— Encrypted ZigBee

— Open ZigBee

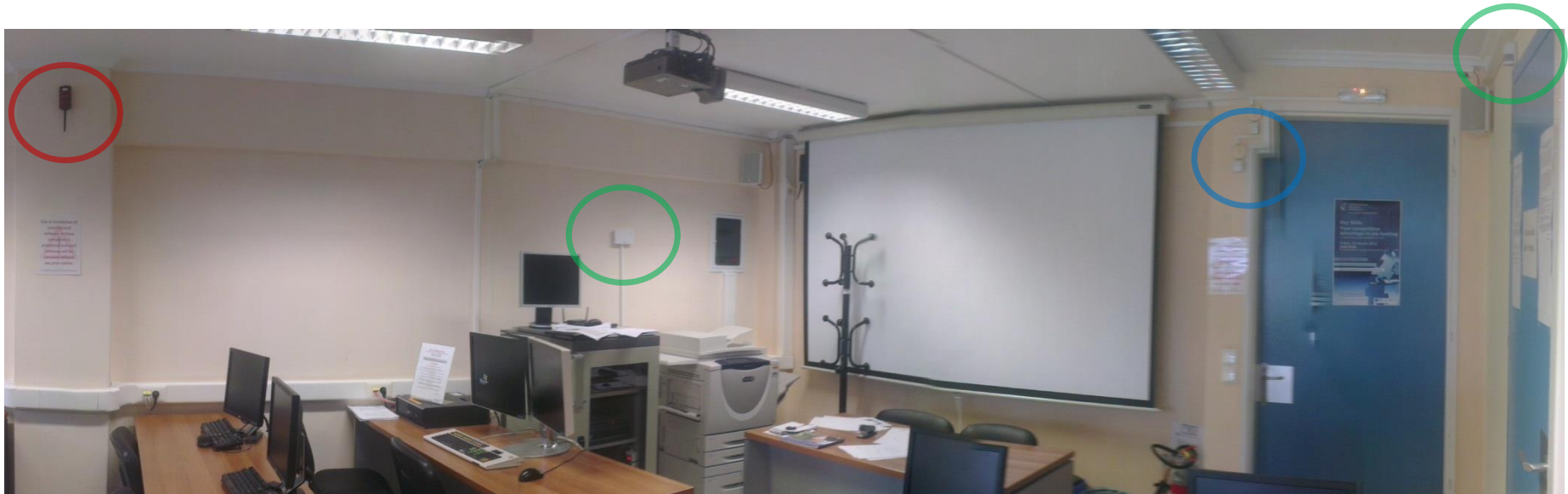
— RF

— Z-Wave

... Wi-Fi

— USB

# Lab 1 Environment



## Prisma Quax

- Temperature
- Humidity
- Luminance

## Z-Wave CO2 Level

## Plugwise

- Read Status
- Read Consumption
- Switch On/Off

Lights, PCs, Fan coils, Printers

## Z-Wave

Motion  
Detection

# Middleware Integration

- A WEb Service MiddlewarE (aWESoME)\*
- Software and Hardware Services
- Re-engineered Drivers and Open APIs
- WSDL standard
  - Syntactic interoperability
  - Universal remote access



## Smart Plug Service

Manipulates the network of Smart Plug Sensor-Actuators, which are able to switch appliances ON or OFF, get their status, and their Power Consumption in Watts.

- [WSDL](#)
- [Tester](#)



## Sensor Board Service

Manipulates the network of Sensor Boards (Multisensors), which measure Temperature, Humidity and Luminance levels.

- [WSDL](#)
- [Tester](#)



## Smart Clamper Service

Manipulates the Smart Clamper sensors, which measure the Power Consumption of main power supplies (I.e. the Data Center and Buildings).

- [WSDL](#)
- [Tester](#)



## Camera Motion Service

Manipulates a simple webcam that detects movement.

- [WSDL](#)
- [Tester](#)



## IT Service

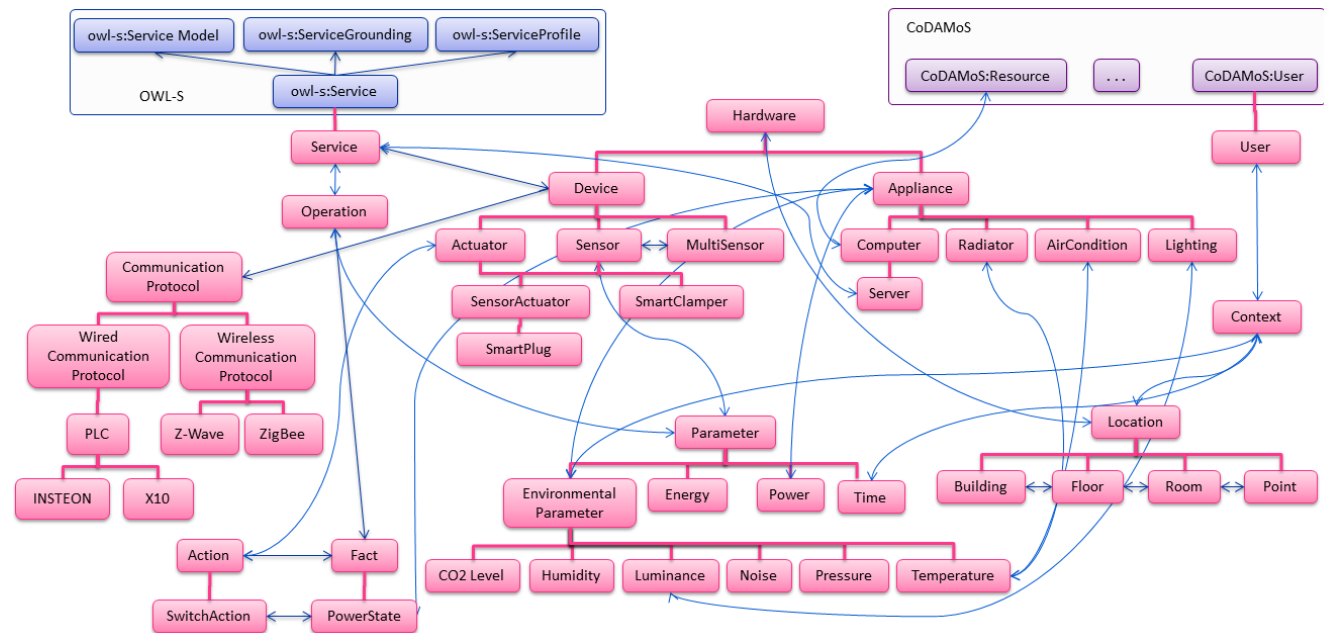
Manipulates the IT infrastructure by turning terminals off (restart, sleep, hibernate) or on (using a Wake-On-Lan implementation). Also returns the CPU Usage percentage of this server.

- [WSDL](#)
- [Tester](#)

\* Stavropoulos, T. G., Gottis, K., Vrakas, D., & Vlahavas, I. (2013). aWESoME: A web service middleware for ambient intelligence. *Journal of Expert Systems with Applications, Elsevier*

# Semantics

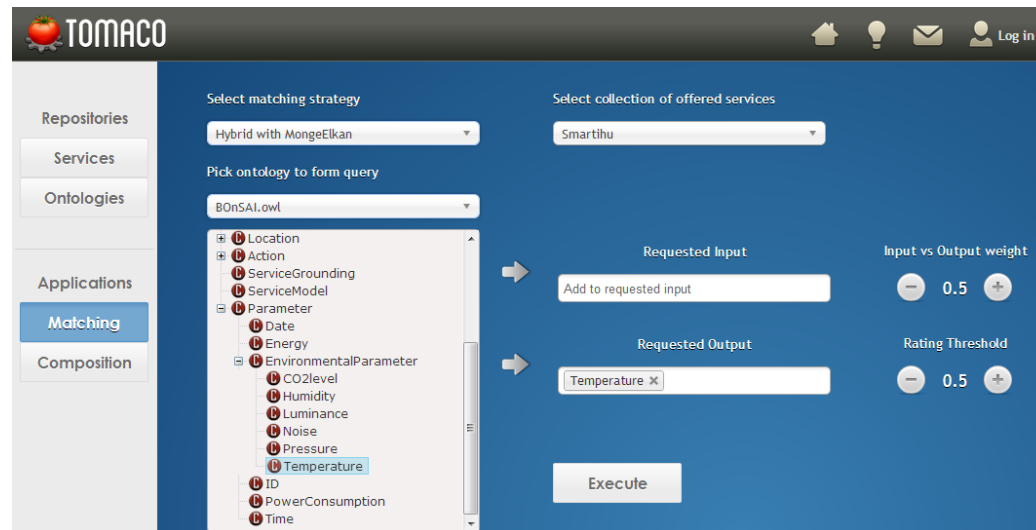
- Enable dynamic/intelligent applications
  - ... by rendering services machine-interpretable
  - Developed tools for describing and annotating with semantics\*



\* Stavropoulos, T. G., Vrakas, D., Vlachava, D., & Bassiliades, N. (2012, June). BOnSAI: a smart building ontology for ambient intelligence. In *Proceedings of the 2nd International Conference on Web Intelligence, Mining and Semantics*(p. 30). ACM.

# Tool for Service Matching and Composition

- Dynamically discover relevant services
  - Logic-, text-based and hybrid algorithm
  - Within and outside Smart IHU
  - SAWSDL-TC dataset, 1<sup>st</sup> in macro-averaging precision



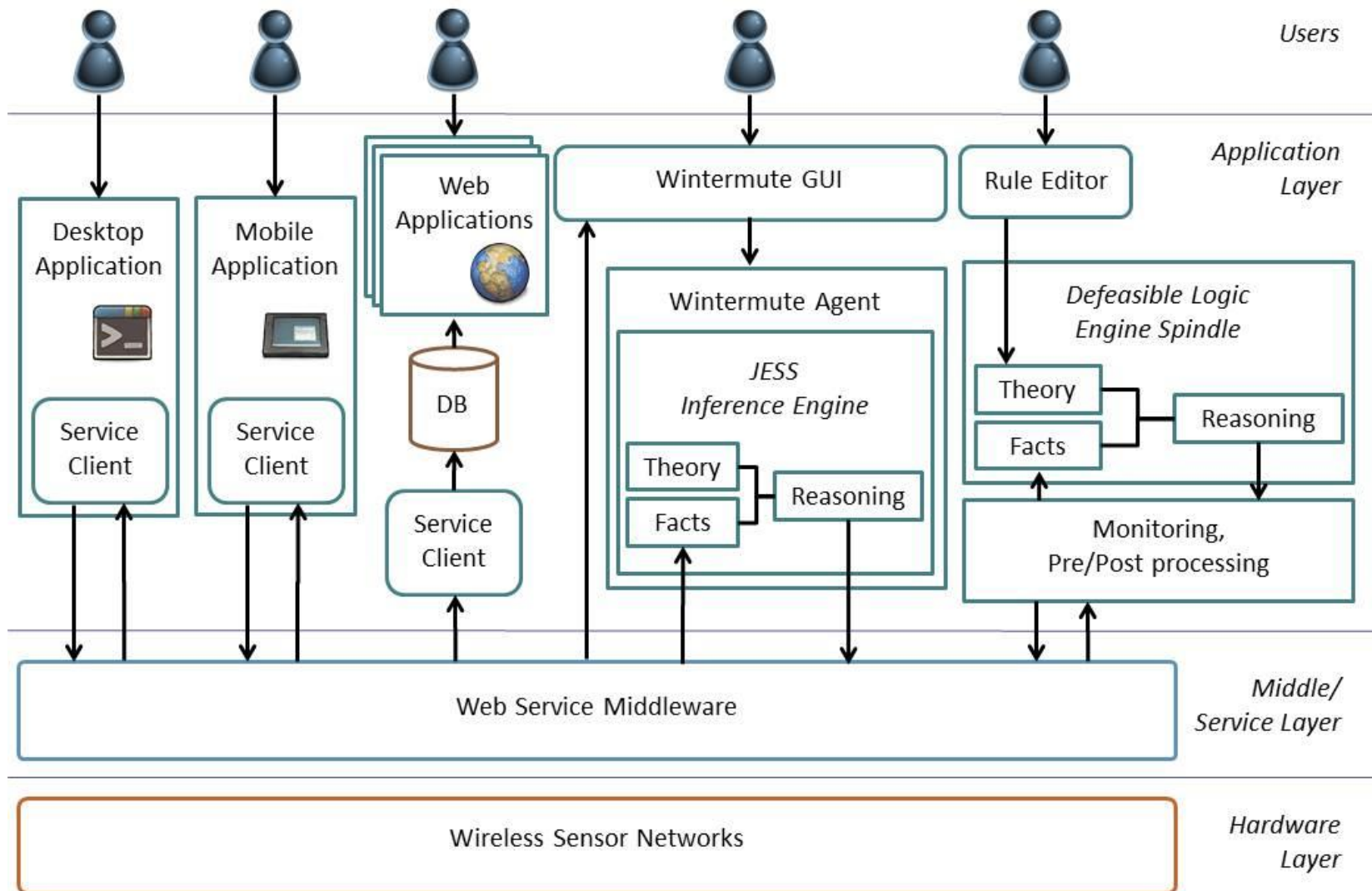
*\* Thanos G. Stavropoulos, Stelios Andreadis, Nick Bassiliades, Dimitris Vrakas and Ioannis Vlahavas "The Tomaco Hybrid Matching Framework for SAWSDL Semantic Web Services", IEEE Transactions on Services Computing, IEEE (to appear)*



# Applications

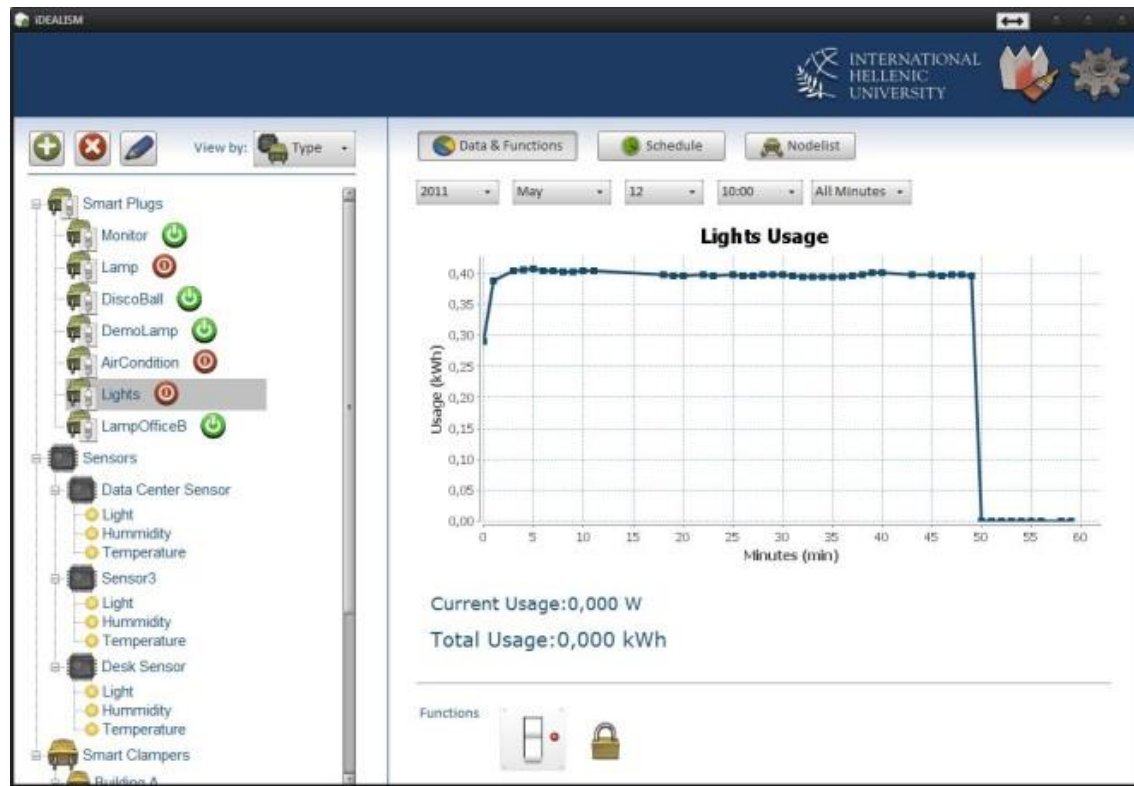
- Administrator Application for Monitoring & Management
- Mobile Application for guests and staff
- Monitoring from everywhere
  - Web application
  - IHU Google Earth model
  - Smart TV
- Intelligent Applications for Savings

# Application Layer Architecture



# Administrator Application

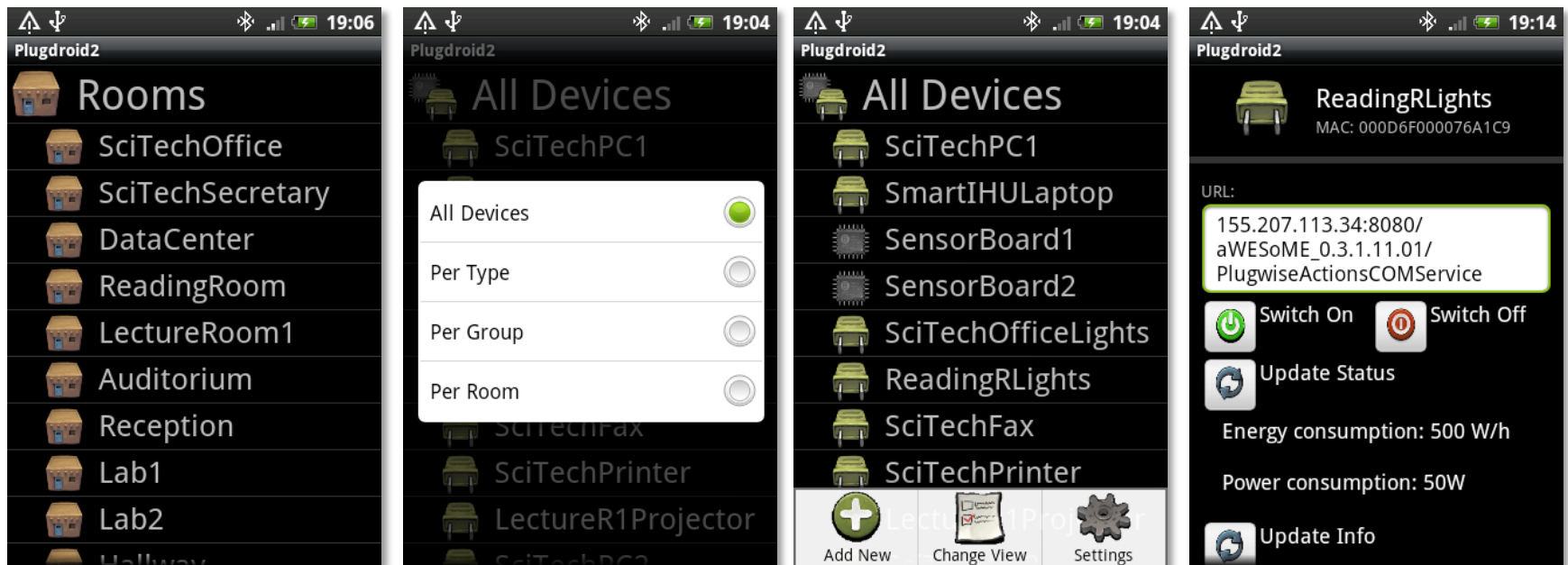
- Full Monitoring & Management



- “Stavropoulos, T., Vrakas, D., Arvanitidis, A., & Vlahavas, I. (2011). A system for energy savings in an ambient intelligence environment. *Information and Communication on Technology for the Fight against Global Warming*, 102-109.”

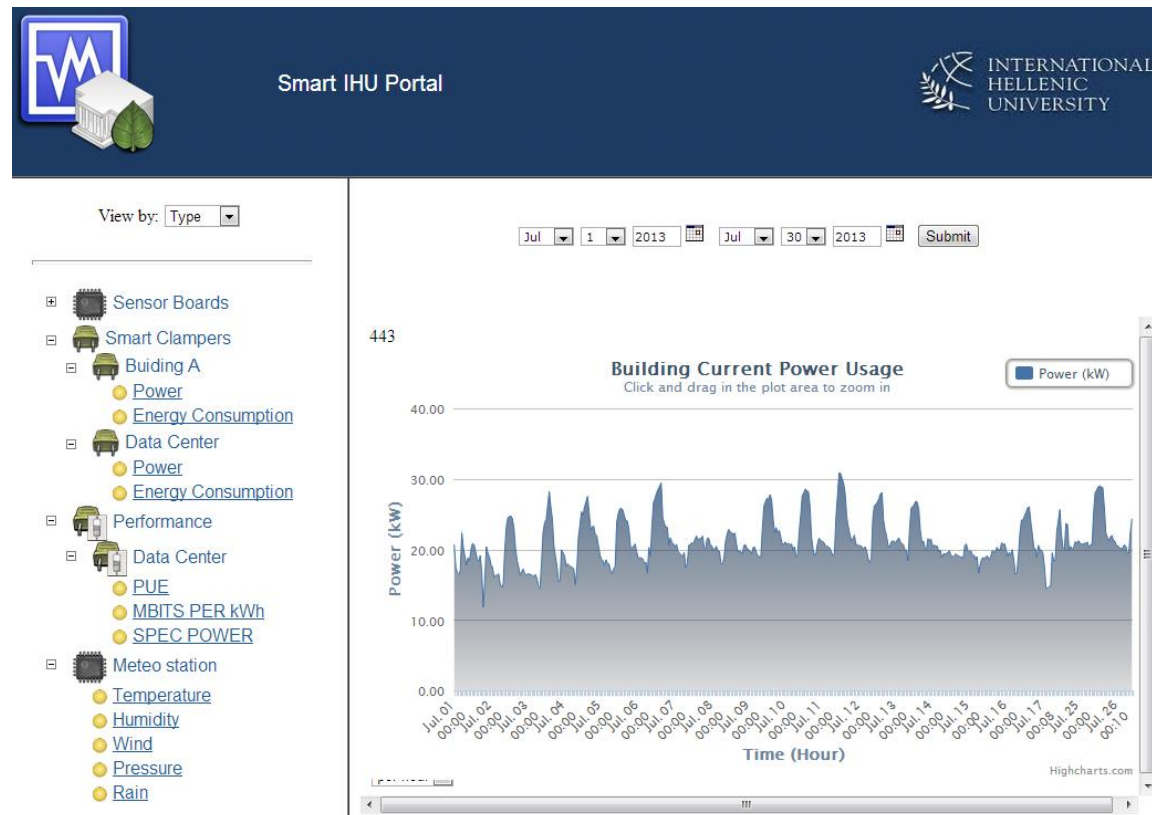


# Mobile Application for guest and staff



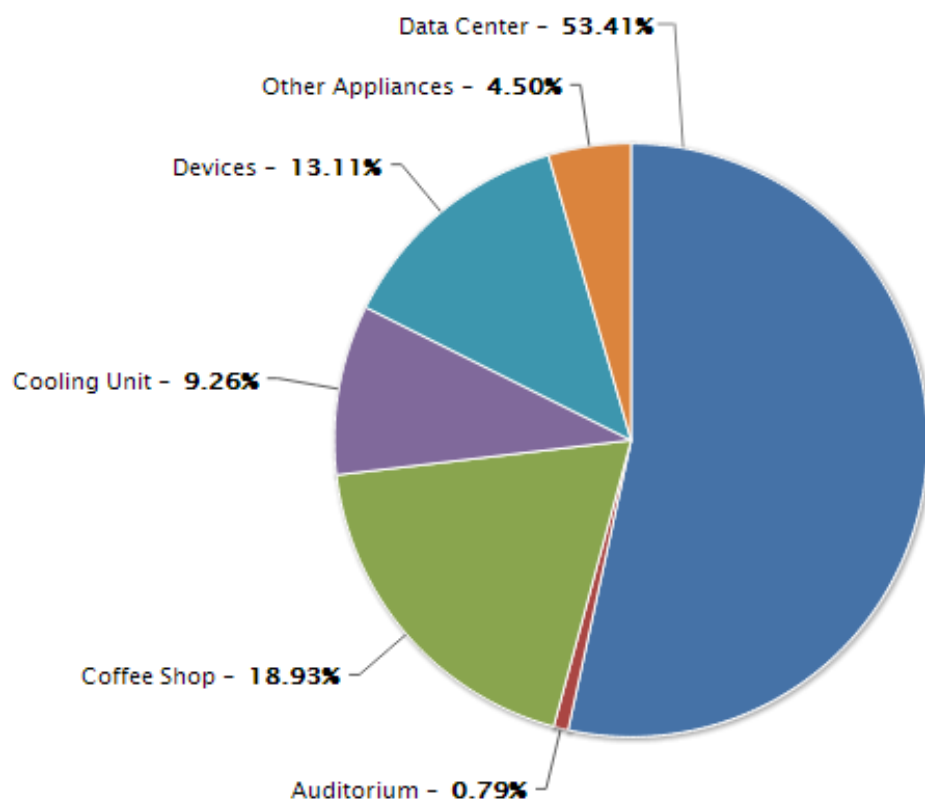
# Web Application @ [smart.ihu.edu.gr](http://smart.ihu.edu.gr)

- Extensive and external monitoring
- Aggregations

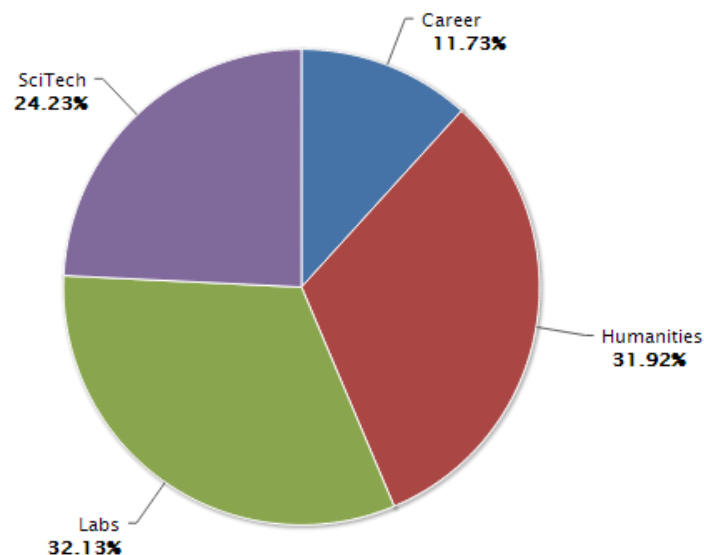


# Distribution of Energy

- Per category
- Per school etc.

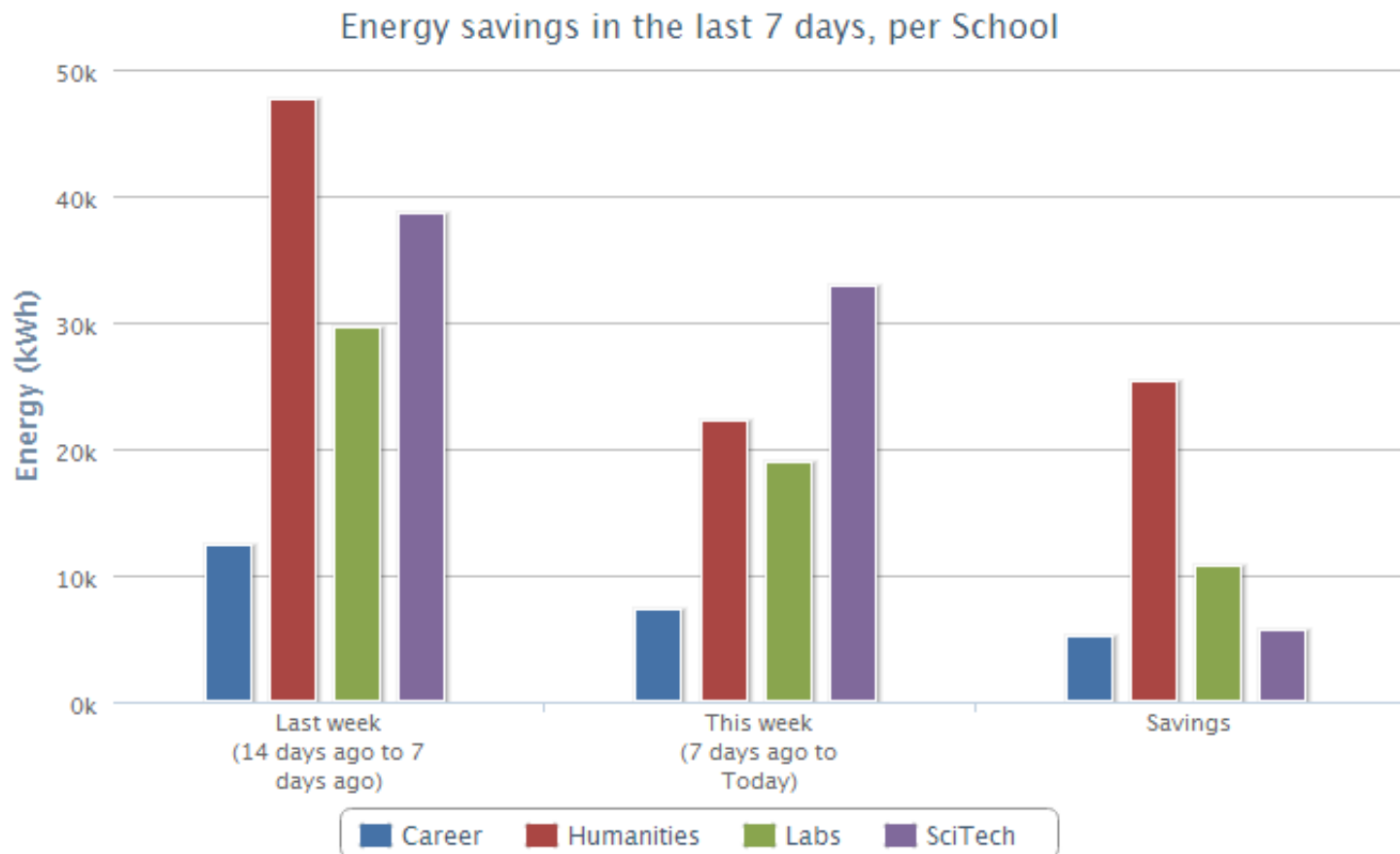


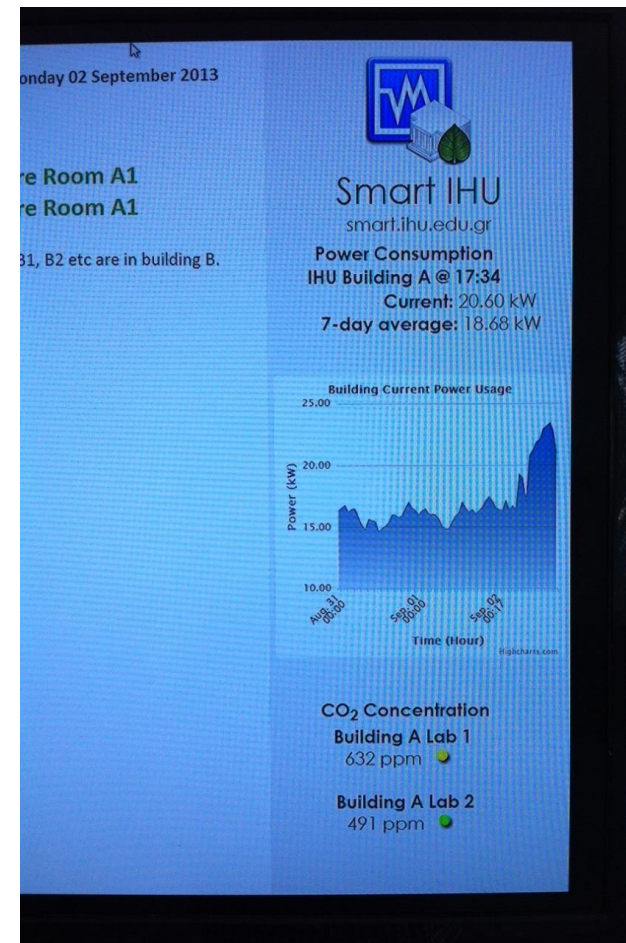
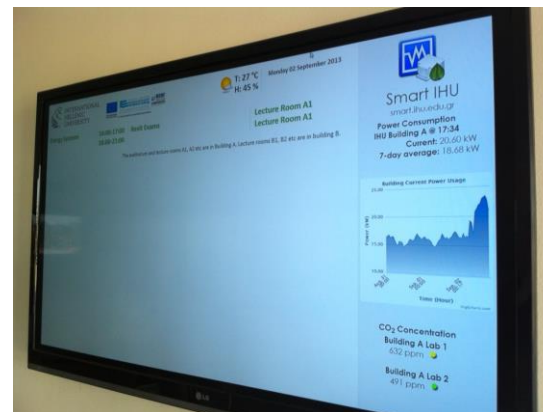
Total Energy Consumption percentages of IHU Schools, Last 7 days



# School Contest

- Gamification prototype





# Smart IHU Pilot Apps



- User-oriented
- Dynamic, distributed deployment and management



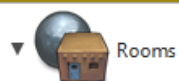
- Rule App
  - Automatically manages devices based on staff environmental preferences



- Manager App
  - Allows staff to manually manage devices, bypass Rule App

# Smart IHU Rule App

Automatically manages and optimizes consumption of Appliances connected to you.



Rooms



CAR1



CAR2



HU1



HU2



LAB1



LAB2



REC



SciTech1








SciTech2




## Room statistics




Power: 55.44 W  
Temperature: 26.06 °C  
Humidity: 44.91 %  
CO<sub>2</sub> Level: No available data  
Luminance: 0.0 cd/m<sup>2</sup>  
Motion: No motion




## Preferred statistics




Airtherm:  




Power:  W   

Temperature:  °C   

Humidity:  %   

CO<sub>2</sub>:  ppm   

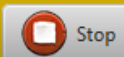
Luminance:  cd/m<sup>2</sup>   

Motion:  sec   

[21:48:29] Finished reading plugs!  
[21:48:30] Monitor is now running...  
[21:48:30] Updater is now running...  
[21:48:30] Monitor loop starts  
[21:49:19] Preferred power set!  
[21:49:36] Monitor loop sleeps for 60000  
[21:50:02] Preferred temperature set!  
[21:50:15] Preferred humidity set!  
[21:50:27] Preferred CO2 set!  
[21:50:36] Monitor loop ends  
[21:50:36] Monitor loop starts  
[21:50:37] Preferred luminance set!  
[21:50:59] Preferred motion freshness set!  
[21:51:02] Enabled motion rule for Room: SciTech1  
[21:51:03] Enabled power rule for Room: SciTech1  
[21:51:08] Enabled temperature rule for Room: SciTech1  
[21:51:09] Enabled CO2 rule for Room: SciTech1  
[21:51:10] Enabled luminance rule for Room: SciTech1  
[21:51:31] Temperature rule: Switch Off Airtherms in Sc  
[21:51:32] Luminance rule: Switch On Lights in Room: S  
[21:51:37] Monitor loop sleeps for 60000



Start



Stop

Interval in minutes:

1.0

Set





Smart IHU Manager App

# Smart IHU Manager App

Manipulate Appliances connected to you and shape IHU's power consumption



## ▼ Active Plugs



LAB1



LAB2



▼ SciTech1



P121 Printer



P17 PC



P16 Airtherm



P316 Lights



▶ SciTech2

Smart IHU ID:

Location:

Appliance:

Type:

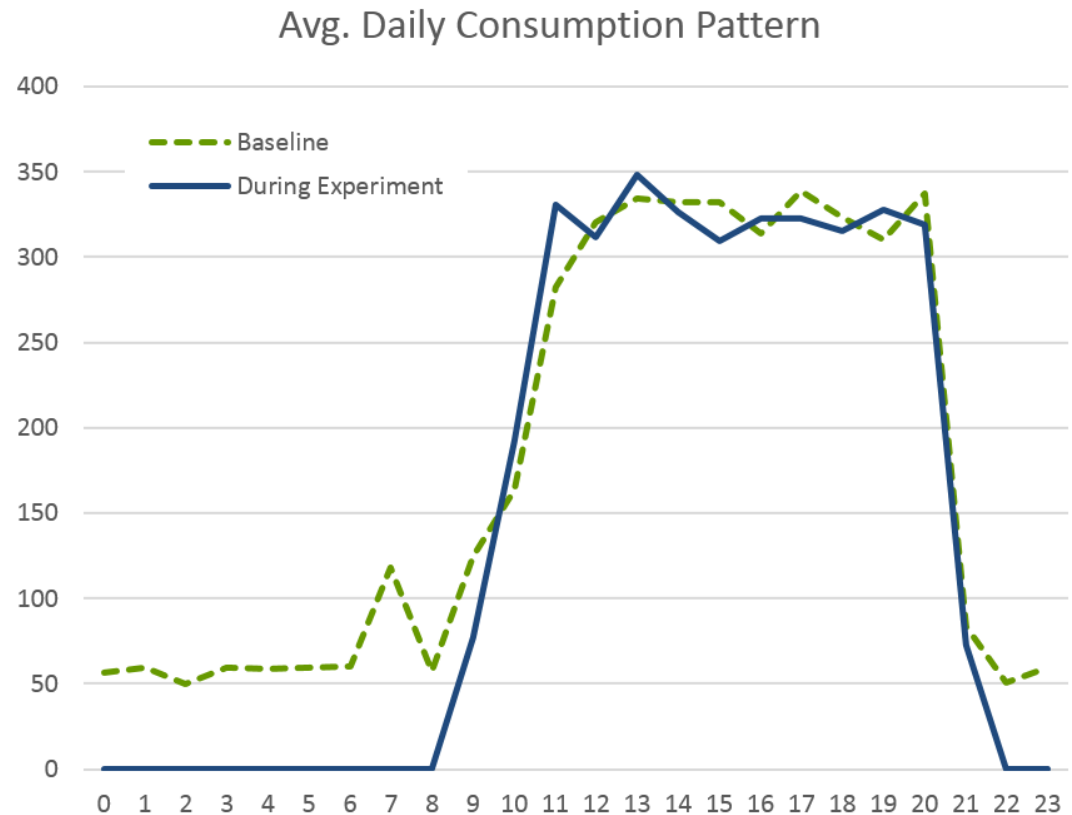
[22:00:46] Loading Database driver...  
[22:00:46] Driver loaded!  
[22:00:46] Connecting to Database...  
[22:00:46] Connected to Database!  
[22:00:47] Database query successfully executed!  
[22:00:47] Loaded 15 Plugs.  
[22:00:47] Closing the connection.  
[22:00:47] Finished reading plugs!





# Results

- Energy Consumption Results
  - 1 office
  - 2 weeks
- 17% savings



# Conclusions

- Vast variety of applications for monitoring, management and savings
  - Achieved deep insight, 17% savings on offices
- Linking R & D and studies with the industry
  - Topics such as Internet of Things, Sensor Web, Smart Grid and Energy
- R & D during studies
  - Applied research in emergent topics

# Future Work

- Security using standards
- Data Mining
  - Forecasting, load disaggregation
  - *Collaboration using our datasets*
- Solar panel integration & Smart Grids (load balancing)
- Extend sensor & actuator variety
  - Shades, ventilation, door & window sensors etc.
- Advanced context-awareness and HCI by combining
  - Visual and Audio Analysis/Recognition and generation etc

# Publications

## International Journals

1. Thanos G. Stavropoulos, George Koutitas, Dimitris Vrakas, Efstratios Kontopoulos and Ioannis Vlahavas "*A smart university platform for building energy monitoring and savings*", Journal of Ambient Intelligence and Smart Environments, IOS Press (to appear)
2. Thanos G. Stavropoulos, Efstratios Kontopoulos, Nick Bassiliades, John Argyriou, Antonis Bikakis, Dimitris Vrakas and Ioannis Vlahavas, "*Rule-based Approaches for Energy Savings in an Ambient Intelligence Environment*", Journal of Pervasive and Mobile Computing, Elsevier, Available online 16 June 2014, ISSN 1574-1192, <http://dx.doi.org/10.1016/j.pmcj.2014.05.001>.
3. Thanos G. Stavropoulos, Konstantinos Gottis, Dimitris Vrakas and Ioannis Vlahavas, "*aWESoME: a Web Service Middleware for Ambient Intelligence*", Journal of Expert Systems With Applications, Elsevier, 40 (11), pp. 4380-4392, 2013.
4. G. Koutitas and L. Tassioulas, 'Periodic Flexible Demand: Optimization and Phase Management in the Smart Grid', IEEE Transactions on Smart Grids, vol. 4, no. 3, 2013
5. G. Koutitas, 'Control of Flexible Smart Devices in the Smart Grid', IEEE Transactions on Smart Grids, (in press), 2012
6. Thanos G. Stavropoulos, Dimitris Vrakas and Ioannis Vlahavas, "A Survey of Service Composition in Ambient Intelligence Environments", AI Review (25 September 2011) pp. 1-24. doi:10.1007/s10462-011-9283-1

# Publications (cont'd)

## International Conferences

1. Thanos G. Stavropoulos, Efstratios Kontopoulos, Dimitris Sfounis, Dimitris Vrakas, Nick Bassiliades and Ioannis Vlahavas, "An Applied Energy Management Approach in Intelligent Environments based on a Hybrid Agent Architecture", AI4IE 2014
2. Thanos G. Stavropoulos, Efstratios Kontopoulos, Emmanouil Rigas, Nick Bassiliades and Ioannis Vlahavas, "A Multi-Agent Coordination Framework for Smart Building Energy Management", IATEM 2014
3. G. Koutitas, L. Tassiulas, 'A Delay Based Optimization Scheme for Peak Load Reduction in the Smart Grid', in Proc. IEEE/ACM e-Energy, Madrid, 2012
4. Thanos G. Stavropoulos, Dimitris Vrakas, and Ioannis Vlahavas, "*Iridescent: a Tool for Rapid Semantic Annotation of Web Service Descriptions*", Proc. 3rd International Conference on Web Intelligence, Mining and Semantics (WIMS' 13), ACM, pp. 12:1-12:9, 2013.
5. Thanos G. Stavropoulos, Dimitris Vrakas, Danai Vlachava and Nick Bassiliades: BOnSAI: a smart building ontology for ambient intelligence. WIMS 2012: 30
6. Thanos G. Stavropoulos, Dimitris Vrakas, Alexandros Arvanitidis and Ioannis Vlahavas, "A System for Energy Savings in an Ambient Intelligence Environment", in the proc. of ICT-GLOW 2011, Toulouse, France.
7. Thanos G. Stavropoulos, Ageliki Tsioliariidou, George Koutitas, Dimitris Vrakas and Ioannis Vlahavas, "System Architecture for a Smart University Building", in the proc. of IEM3 workshop in conjunction with ICANN 2010, Thessaloniki, Greece.

# Thank you

- More information
  - <http://smart.ihu.edu.gr>
  - <http://rad.ihu.edu.gr/smartihu>