Eco - labeling Greek schools for energy efficiency over IPv6

K. Koumoutsos, E. A. Varvarigos
Department of Computer Engineering and Informatics, University of Patras, Greece
Computer Technology Institute "Diophantus", Greece
koumoutsos@cti.gr, manos@ceid.upatras.gr

V. Nikolopoulos[1] A. Liakopoulos[2]
[1] Intelen Advanced Engineering Division, Cyprus,
[2] Greek Research and Technology Network, Greece,
v.nikolopoulos@intelen.gr, aliako@grnet.gr

***Abstract*— Reducing CO_2 emissions in order to address climate change is a difficult challenge but it may also become an opportunity for improving citizens' behaviour towards the protection of the physical environment. Furthermore, as buildings are responsible for a significant portion of total energy consumption and emissions, improving their energy performance is clearly a key factor for accomplishing the EC climate and energy objectives. In this context, the Greek pilot in GEN6, a European Commission funded project, aims to influence the behaviour of the local school communities by raising their energy awareness. As discussed herein, the pilot will provide real-time energy efficiency services over IPv6-enabled grids to the local educational community, providing students with information on their consumption patterns and raising awareness among them on the energy savings that behavioural changes may bring. Consequently, the pilot aims to reduce the participating school buildings' carbon footprint by at least 10% and prove that IPv6 may become an enabling technology for new advanced services. Currently, the installation of IPv6-enabled energy smart meters is in progress at 50+ schools for monitoring energy consumption but also for becoming an educational and social engagement tool for students. The GEN6 pilot, also aligned with the Greek School Network energy innovative programme, is further reinforced by hands-on workshops aiming at engaging students on issues of sustainability and empowering them to make further behavioural energy-saving changes. Results from the competition among the participating school communities are disseminated to the public through various means, such as a web portal, a blog, and social networks, which record the energy efficiency of participating schools and the effect of the actions taken.**

Keywords: IPv6, smart energy meters, energy efficiency

I. INTRODUCTION

Reducing CO_2 emissions in order to address climate change is a difficult challenge but it may also become an opportunity. As buildings are responsible for 40% of energy consumption and 36% of EU CO_2 emissions [1], improving their energy performance is clearly a key to achieving the '20-20-20' EC Climate & Energy objectives; 20% reduction in emissions, 20% renewable energies and 20% improvement in energy efficiency by 2020.

Recent advances on energy metering and energy efficient equipments have been partially adopted in public and residential buildings. Informing the public, and especially the primary and secondary education community, about energy-efficient behaviour and the new energy-related technologies usually requires significant time, effort and resources, possibly more than the ones a typical organization is willing or able to spare. In addition, the financial benefit that is a determinant factor for the adoption of "green" technologies and best practices is also generally difficult to be accurately estimated and appreciated.

Citizens' behaviour is an important factor that determines the overall energy consumption of buildings, and may be improved through energy awareness. Results reports indicate that energy-efficiency behaviours account for 51% and 37% of the variance in heat and electricity consumption between buildings, respectively [7]. An energy consumer that is able to know in real time the energy consumption that his/her behaviour is causing and compare it to that of other similar users is more likely to initiate changes. The term energy awareness implies the training of a user in terms of understanding how much his actions and his use of appliances contributes to total consumption, and helping him plan specific actions that could lower consumption in a quantifiable way. The acquired knowledge may be used as follows:

- as the basis for extending the consumers "self-training" to more complicated issues, e.g., understanding correlations between the energy consumption and usage of different sets of appliances, or obtaining a practical meaning of terms and metrics, like reactive power and Watt-hour,
- as the starting point for understanding the connection between personal power consumption and carbon emissions, thus shaping or strengthening the individual "green" consciousness,
- for spurring the user's interest towards inventing strategies for reducing the personal energy needs by cutting off wastes without sacrificing personal comfort.

Given the energy scarcity problem and the consequent need for its optimal use though user awareness, a set of smart energy power meters have already been installed into 10 schools for the real time monitoring of their energy consumption. The school energy awareness and efficiency campaign will be scaled during 2012 to over 50 Greek schools. The innovative and educational pilot implemented by the Computer Technology Institute (CTI) [11], Intelen [2], and the Greek Research and Technology Network (GRNET) [12] on the Greek School Network (GSN) [3], aims at encouraging and enabling students to change their

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behaviour so that it becomes more energy and environmentally friendly. The goal is to reduce the schools' energy consumption by at least 10%, even though much larger savings have been reported in our initial installations. The installed smart meters measure and push the energy consumption data to a scalable cloud aggregation system via a secure communication channel over IPv6. Groups of students will be in charge of monitoring their school's energy performance through the use of the interactive web platform. Via an real-time intuitive interface, the school community will be taught the correlation between the actions they undertake and the energy consumption/CO2 emissions of their schools, providing in this way significant motivation for behavioural changes. Moreover, the IPv6 web based platform will become an educational and social engagement tool for students, stimulating discussions and actions within schools related to the energy consumption and its environmental implications.

At the final stage, the students will be given the opportunity to participate in a series of interactive workshops designed to develop their knowledge, equip them to take action to address issues of sustainable living, energy consumption and climate change, and motivate them to make further behavioural changes. Results from the competition among the participating school communities are disseminated to the public through various means, including a web portal, a blog, and social networks.

II. Architecture Topology

The architecture of energy smart meters infrastructure is shown in Fig. 1.

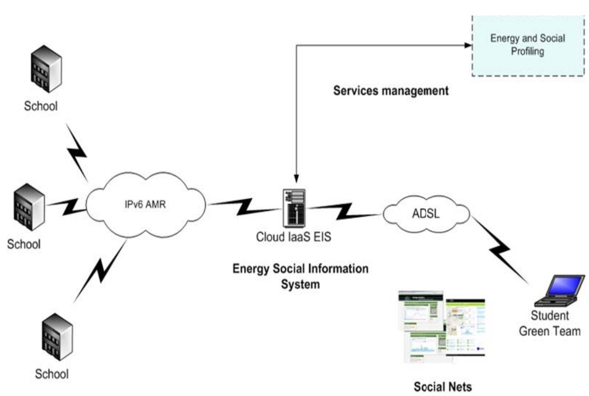

Figure 1: Logical topologic of the Greek Pilot in Schools

The installed power meters in schools collect energy consumption data that are aggregated through Greek School Network via IPv6 to Intelen's cloud based system. The cloud based system feeds the interactive web platform and schools' pages with distributed energy data management and stream analytics. The primary internet connection in schools with installed power meters is broadband (xDSL) connection with IPv6 characteristics. As discussed in section IV, enabling IPv6 in the current infrastructure increases service reliability as well as efficiency for data management and control. In addition, the planned dissemination activities will further increase the energy awareness and cause behavioural changes in the school communities. Motivation techniques for student engagement will be boosted, using direct access over IPv6, using a web portal and dashboards.

The smart metering infrastructure in each school building is shown in Fig. 2 and consists of a consumption metering device (abbreviated CMD) along with its current transformers (CTs), a transmitter and the "i-box".

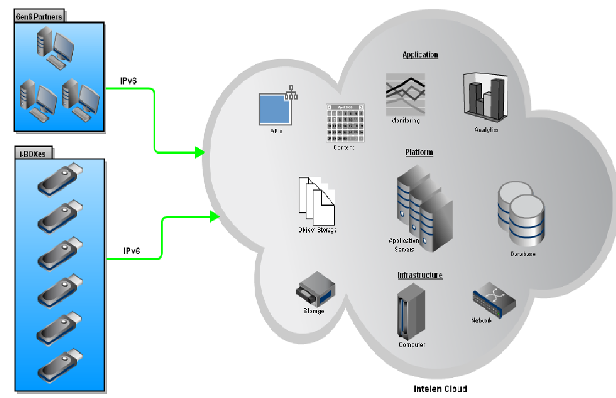

Figure 2: Intelen's Cloud Infrastructure

The latter is a smart device that acts as a data bridge between the meter and the internet and is capable for a series of services, including the following:

- It performs basic calculations in order to translate the raw data that are collected by the specific CMD to information that can be handled by centralized (cloud) infrastructure,
- It acts as memory storage (buffer) so that in case of a network or other error, data are not lost, but are stored for transmission when network connectivity is re-established,
- It extracts the appropriate key performance indicators (KPIs) from the raw data received by the CMD,
- It receives instructions for extra KPIs from Intelen's Meter Data Management (MDM) System,
- It performs error handling concerning the CMD, the connectivity of the system and the i-box itself.

The collected data is stored, aggregated if necessary, and analyzed in Intelen's Cloud through IPv6. Energy data will be available through Intelen's APIs in JSON, XML, plain text, HTML and CSV format. The most appropriate format is JSON due to its flexibility and the smaller size of its files. The available API methods will include: daily data in one-hour intervals; monthly data in one-day intervals; yearly data in one-month intervals.

III. IPv6 in Greek School Network (GSN)

The Greek Schools' Network (GSN) [3] is the educational intranet of the Greek Ministry of Education [4], Lifelong Learning and Religious Affairs , which interlinks all schools and provides basic and advanced telematics' services. Thus, it contributes to the creation of a new generation of educational communities, which make use of the new Informatics' and Communication Technologies in the educational procedure. GSN is a nationwide network that spans to all fifty one (51) prefectures of Greece. The majority of schools in Greece, approximately 95% of them, are connected to GSN using ADSL technology.

The Greek School Network already supports IPv6 interconnection services and other basic services over IPv6. Such services are gradually extended in the intranets within schools (approximately 15.000 sites). The backbone network of GSN is fully IPv6 enabled including IPv6 support. On the access network, IPv6 interconnection has been activated for the ADSL users, i.e. for 95% of the schools. This has been achieved by enabling IPv6 on the LNS and on the radius profiles of each ADSL router connected to GSN. The process is described in more detail in Figure 3.

IV. Smart Power Meters and IPv6

Smart metering generally involves the installation of an intelligent meter, the regular reading and processing of energy-consumption data, and the provision of feedback on consumption data to the customer. The "smart" meter has the following capabilities: (a) real-time or near real-time registration of electricity use, (b) local and remote access to the meter, on demand, and (c) remote limitation of the throughput through the meter (in the extreme case cutting of the electricity to the customer). The installation of IPv6-enabled smart energy meters to schools is important in overcoming some important challenges:

- The management overhead for interconnecting a large number of energy smart meters is reduced as NAT gateways are removed with the deployment of IPv6 on GSN
- Better policy schemes over heterogeneous networks are made possible; for example, nodes of various on-site communications systems can be provided with unique public IPv6 addresses to avoid conflicting use of private IPv4 addressing; centralized communication initiation and management can be provided and services can be directly connected as all nodes across different on-site networks can have globally unique public IP addresses
- Advanced security features to the schools intranets are enabled; for example, transparent end-to-end security without complex NAT traversal mechanisms, fine-grained security policies and filtering rules can be applied based on unique end system addressing scheme
- Advanced auto-configuration features (e.g., IPv6 stateless auto-configuration) and ad-hoc routing are made possible
- Quality of Service (QoS) can be supported in local and global network environment
- Multicast transmission features are enabled
- Facilities are provided to deploy new services without NAT-related limitations and requirements for application gateway implementation (e.g., exchange of sensor data, services for situation monitoring, etc.).

V. Role of Social Networking and other Student Engagement Tools

Van Dam et al. [8], found that the introduction of energy monitors in buildings results in a distinct decrease in the level of energy savings originally made by occupants after only a few months. This is attributed to a lack of habit formation as well as poor design with overly complex interfaces. The authors showed that where people adopt a regular habit of looking at energy monitors on a daily basis, they exhibit larger savings over time compared with others. An implication is to question the notion of mass-produced 'one-size fits- all' home energy monitors and whether solely technological solutions (such as energy monitors) will actually achieve the desired results. It also suggests that a deeper understanding of the relationship between the user and these systems is needed. Darby [9] also discusses the level of 'affordance' that smart meters offer, i.e. their usability and effectiveness and points out that: "Taking control away from the customer cannot be relied upon to improve the situation: it may actually entrench and legitimize high-demand practices, disengaging customers from any need to consider and question them". Darby argues that effective forms of interface, feedback, narrative, and support need to be developed to reach more diverse populations and to reduce actual consumption. The challenge is for the smart meter to prove itself in terms of developing a useful relationship with the user, through new forms of user engagement (understanding, expectation and behaviour) enabled by new design and media approaches.

To address these issues we have developed a web based platform that illustrates to the students the correlation between their actions and energy consumption/CO_2 emissions of their school, targeting to become an educational and social engagement tool for students. This platform will be used to motivate a kind of competition among schools regarding which of them will achieve the most significant energy savings. It will also be used to stimulate discussions and actions within schools related to the energy consumption and its environmental implications. We also plan to use social media to promote energy efficiency and sustainability campaigns not only into school community but also in the Greek public sector infrastructures. The social media campaign program will be reinforced by hands-on workshops that engage students on issues of sustainability and empower them to make further behavioural changes. Results from school energy competitions will be create interaction among students. All these activities provide detailed information for the energy efficiency of the schools participating to the project, creating "social media traffic".

VI. Pilot Results from 10 school buildings

In this section we present our initial results for the deployment of smart meters at 10 (out of the 50 schools). The total energy power savings for these 10 school units over a period of 10 weeks was 12.234 KWh. The calculated monetary benefit is 3.500€, when the electricity school price for energy unit is 0,12€ per KWh. The extrapolated power saving per school year (40 weeks) is 48,936 KWh.

The power energy saving results in KWH from ten schools after the period of ten weeks is presented in Table 1.It should be noted that the 1st and last week (week 1 and week 10 after normalization) in consumption were used in normalized statistical indices.

School Name	Power Saving
1st High School Haidariou	21,30%
8th Primary School Vyrona	24,06%
70th Primary School Athens	39,30%
10th Primary school Haidari	33,38%
7th High School Haidari	36,10%
152th Primary School Athens	38,26%
7th High School Peristeri	39,91%
8th Primary School Dafni	33,39%
1/7th Primary School Athens	31,22%
59o High School Peristeri	37,60%

TABLE 1: POWER SAVING IN KWH

Table 2 depicts useful details and school characteristics such as school density, school population, cumulative average energy consumption before and after the pilot installation at the 10 schools, and finally the cumulative average energy saving per day.

No. of Buildings	10
Av. School Sqm2	~1800 sqm2
Av. Student population	~250 students
Av. Energy / day consumption before smart energy meters	96.1 KWh
Av. Energy / day consumption after smart energy meters	71.7 KWh
Av Energy savings / day	25.39%

TABLE 2: SPECIAL CHARACTERISTICS

The approximate extrapolated statistics for one school year (consisting of 40 school weeks) is presented in Table 3.

electricity price for schools	0.12€/kWh
Value of savings in 10 weeks	5,872€
Annual consumption at start (280 days)	26,908 KWh
Annual consumption per student	108 KWh/student
Value of annual savings	5,872 €
Value of annual savings per student	2.35€/student

TABLE 3: EXTRAPOLATED STATS

Table 4 represents some brief but important results that we had, following a simple Demand Response (DR) pilot, during these 10 weeks, for the engagement of the students. The graph in Table 4 represents the engagement efficiency in % to the Demand Response signals that were sent to the student teams, in order to reduce their demand consumptions by specific targets in a specific timeframe (i.e., drop by 1,4KW in the next 30mins). The DR signals were sent using mobile SMS and email to the teams responsible. During the 1st weeks, the DR efficiency rose from 65% up to 74% and then was stable, fluctuating over a median. This means that from the initial DR targets, the schools were able to respond to the DR signals with some delays (~15-20 mins) and to meet their initial DR targets (drop in KW) approx by 75%. Thus the average DR efficiency reaching goal is calculated for every school for each week, as the efficiency of the transition speed (mins) and the efficiency of the target demand (KW). The dynamic average during the 10 weeks can be seen in the figure, indicating the amazing engagement progress that the students and schools have shown, towards Demand Response and energy efficiency targets.

VII. CONCLUSIONS

The lack of the energy consumers' knowledge about their own electricity usage is a significant problem but also an opportunity for the public and private stakeholders to save money and fight against global warming by reducing CO2 emissions. Informing the student communities about how much energy is consumed by their actions, in real time, is a critical issue for the energy consumption optimization of school buildings. The Greek School Network energy innovative program and the relevant GEN6 pilot aim at reducing the schools' carbon footprint by at least 10% and to offer advanced real-time energy efficiency services over IPv6-enabled grids. It focuses on positively affecting the students' behaviour and raising energy awareness within the school communities. The installed energy meters demonstrate to participating students in real time the energy consumption and environmental implications of their actions, providing in this way significant motivation for behavioural changes. Given the long lifespan of most governmental buildings (including schools), the relative energy efficiency of school buildings will influence energy consumption for many years in the future. In addition, the aforementioned activities are greatly facilitated through the use of IPv6 technology. Finally, the dissemination plans that will be carried out within the schools and the wider educational community will establish a strong collaboration framework between the ICT sector, the smart building & automation vendors and the public authorities.

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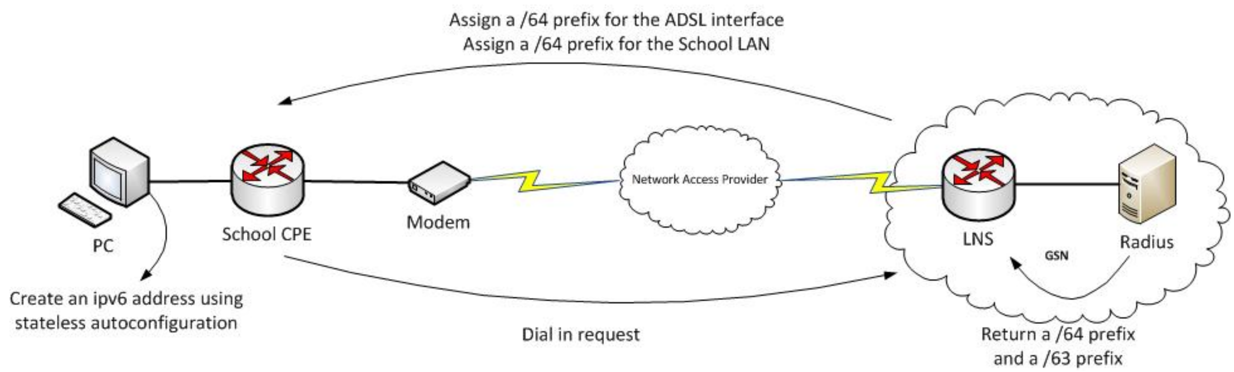

Figure 3 IPv6 assignment to a broadband (ADSL)-connected school.

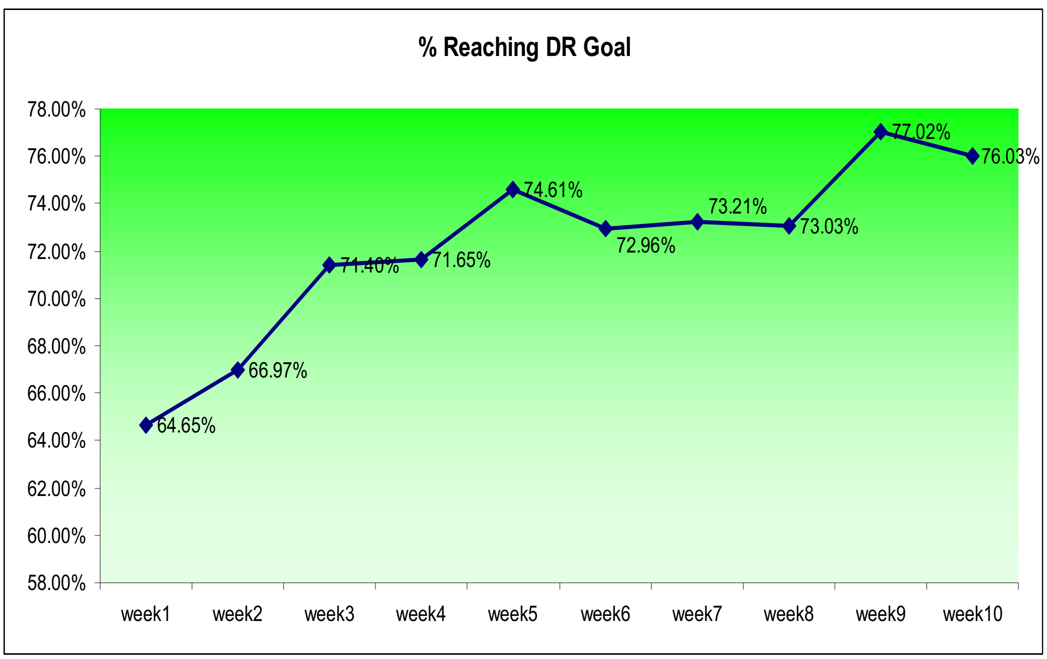

TABLE4 : ENGAGEMENT EFFICIENCY IN % TO THE DEMAND RESPONSE SIGNALS THAT WERE SENT TO THE STUDENT TEAMS