Greendel

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Team Clover

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Software Design and Interoperability Award

Problem

Problem Description

When people consume resources in a household, they are not immediately aware of the consequences of their actions. Especially when it comes to consuming electricity, the feedback for consumption can come months later. When people are not aware of the exact relation of using electrical devices and the power consumption, they might accidentally consume more resources than necessary and at the same time get a larger electrical bill. When fossil fuels start to run out and more households are starting to turn to using local renewable resources for power generation, people are not used to regulating their own power consumption despite being responsible for producing a part of their own electricity.

Solution

Our solution is to provide a full system for monitoring power consumption and local power production by leveraging the latest web, mobile technologies and cloud computing. This solution is called Greendel, which is a system that combines all the different elements into one cohesive system. We believe that by showing the relation between different actions and energy consumption, the users of Greendel are encouraged to regulate their energy usage. As local renewable resources are becoming more common in households, the users will already have the proper mindset of thinking about their energy usage. The ultimate goal of Greendel is increased savings to the user and the conservation of natural resources. The cycle of ideas is presented next page in the figure one.

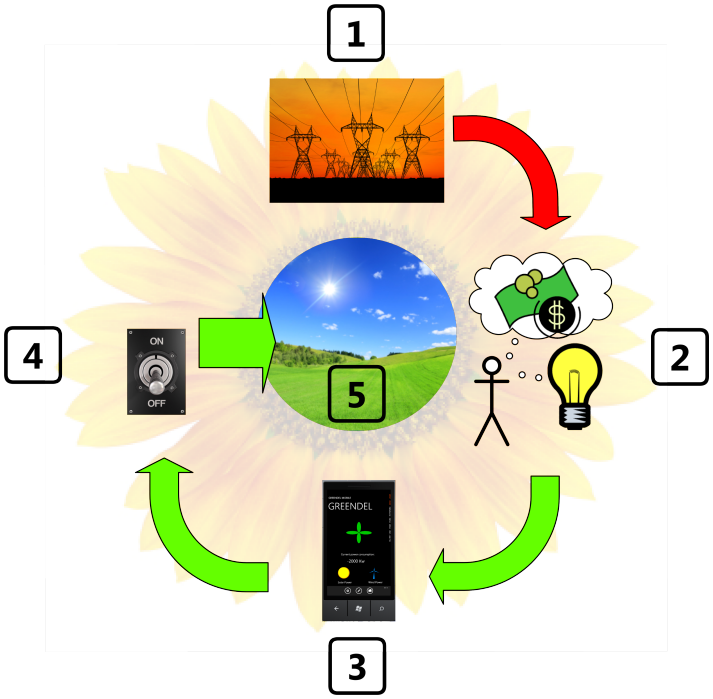

Figure 1. The Project Greendel vision

Business Cooperation

Team Clover is not alone in working on the Greendel solution: In addition to software and online services, the project needs hardware solutions and cooperation in order to aquire energy readings both from inside the household and outside energy production networks. While the team is able to create all online and software services, hardware components require production capabilities. Also, cooperation with companies can bring the system to a wider scale of users. Initially, one company have been contacted and is interested in utilizing the system.

Settek Oy was contacted for their competence in industrial automation and custom electrical solution manufacturing. They are able to provide anything from home appliance level power meters to large, industrial electrical installations. Additionally they have had some experience in installing renewable energy power generation devices, and are interested in further development of novel, competitive solutions.

System Design

The Greendel system combines several different components into one service by using a centralized web service that harnesses the power of Azure cloud hosting. The scalable web service retrieves power consumption data from several different sources and sends it to the different types of client applications used by the customer.

The main components of the Greendel solution are programmable logic unit (PLC), embedded client device, web service, and client applications. PLC and embedded client device are installed to the electrical utility meter in customer's house. PLC gathers the power consumption data as well as other relevant information, like inside and outside temperature. Embedded client device reads this information from PLC and sends it to the Greendel web service that runs in the Azure cloud platform. User receives this information to his workstation or mobile device with Windows Phone 7. The information is displayed as graphs and figures from different periods of time.

By seeing the real time power consumption, the user of Greendel solution can take certain actions to diminish it by controlling power consuming devices, such as heating and lightning of the house. The user is provided with statistical information of his power consumption and production. The user is able to see if the power consumption is above or below the desired level and how much money he would save if the consumption stays at the certain level. If the household is completely dependent on renewable energy sources, like solar and wind power, Greendel can tell the user how much power is produced and how much is left in the batteries. Based on this information, user can see, if the backup generators need to be started and life becomes easier when one no longer needs to worry if there is enough power left for daily activities.

By connecting Greendel with external Web services such as weather forecast services, the users can and see how the season and weather affect on the power consumption. It is also possible to co-operate with electrical companies and connect Greendel to their Web services in order to get more data, for example the current prices of electricity. By connecting Greendel with social media, the saving of power consumption with Greendel can be fashionable as users can upload the results of their successful savings to for example Twitter.

Features and Technology

The following list details the most important functionality available in the program.

Features

- Records and presents power consumption statistics
- If in use in the household, records and presents power production statistics
- Allows connection of home automation devices and home automation control
- Collates all display of data and embedded device control to both
  - web page
  - mobile phone
- Summarizes and shows history of power consumption, generation, weather environment and status of connected devices
  - Either at utility meter or device level
- Can parse and consume information from web services (e.g. power consumption data from the power company web service)

Technology

- IronRuby on Rails web service and web UI
  - Runs on the scalable Azure cloud platform, making it IronRuby on Rails on Azure
  - Uses the SQL Azure cloud database for the data storage backend
- Windows Phone 7 mobile application, with Silverlight UI and C# application logic
- Visual Studio used for IronRuby and C# development
- Expression Studio used for Sliverlight design

Architecture

The Greendel system is composed of several different elements, which run on a variety of hardware and software platforms. The figure 2 below details the data flow between the components and the how they interact in the system. The web service, running in the Azure cloud, can consume data from several different components using an XML-based protocol. It can receive data from the Greendel Project's embedded device or, if available, the power company's web service. Similarly, it can provide data to a variety of client programs using the same protocol. The project's embedded device can communicate with proprietary power measuring devices with industrial ethernet protocols. The power measuring devices get direct power consumption data by connecting with the power meter or individual home appliances. Data can be published to external services, like some social media services.

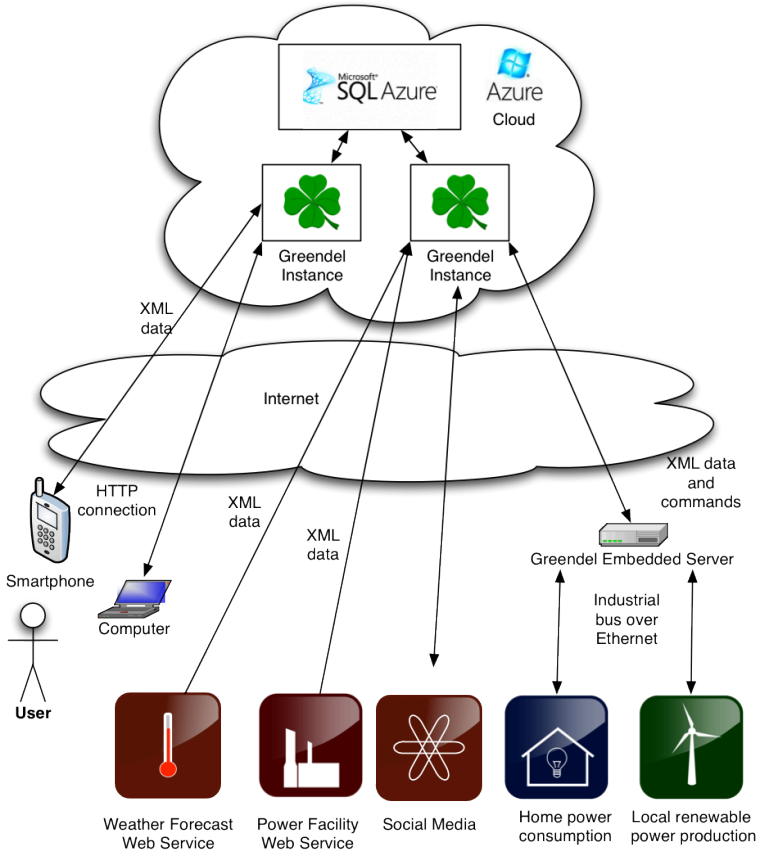

Figure 2. System component connectivity

Interoperability

The system uses a flexible architecture where the different components are coupled using a centralized but scalable RESTful web service. This and an XML-based communication protocol ensures maximum compatibility for a very large set of clients. The web service can interact with as diverse clients as Windows 7 smart phones and Linux-based embedded devices using the same protocol, bridging diverse technologies into one cloud-based system.

In case data sources have proprietary data formats, the system can be adapted with parsing plugins in order to maximize compatibility with outside data sources. This is important, because the centralized system has to be able to retrieve data from outside web services and for example weather forecast sources.

Users and Use Cases

The Greendel system has one group of users: Homeowners who are interested in monitoring their power consumption and renewable energy production. The following figure 3 shows several different use cases that are available to the users of the system.

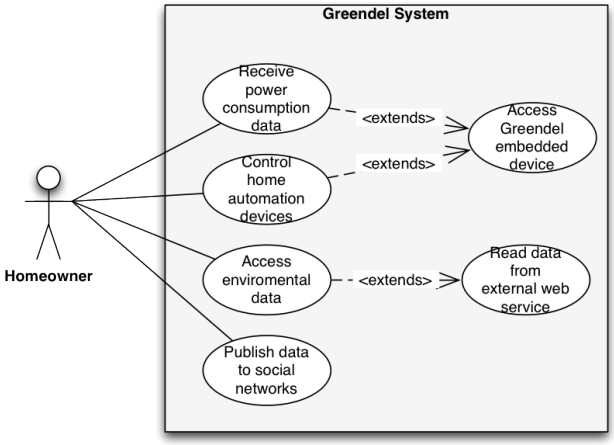

Figure 3. Greendel system use cases

The user can access all the functionality either through the web interface or the phone interfaces, but in some cases the web interface has more details available because of the limitations of the display devices. Users are not only limited to viewing the information themselves, but for example they can share the savings they have reached through social media services. This can create a sense of community, when they see that they are not the only people who have started to look for ways to save energy.

User Interface Experience

The user interface of the Greendel mobile application is simple but powerful. The user can get the most relevant information with one look. The user experience of mobile application has been increased with animations that immediately direct attention to important data. The main screen, presented in figure 4 on the right, displays the current power consumption with an animated clover icon. Icons for presenting states of the possible renewable energy sources are also displayed in the main screen. At the bottom of the screen, there are menu buttons that user can use to navigate to settings, control and history screens. From the control screen that can be accessed from the main screen, the user can see temperature information from sensors and turn on/off lightning or heating of the household. Application settings can be adjusted in settings page. History page shows archived information of power consumption from desired periods of time.

The Greendel web application expands the functionality available for users. For example, it allows more detailed access to the available history data and extends the social networking options. While the web interface has not been for one specific device, this has not been allowed to detract from the user experience. It harnesses the AJAX and JavaScript technologies to deliver an interactive user experience to a wide array of different devices.

Figure 4. Mobile client main screen