SEVENTH FRAMEWORK PROGRAMME

GreenDataNet

D2.1 – Smart Monitoring System

Final

[Manager]

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Rev 2.2

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REVISION SHEET

Revision Number	Date	Brief summary of changes
Rev 1.0	20/09/2014	Baseline document
Rev 2.0	28/09/2014	Revised version of specs and figures added
Rev 2.1	30/09/2014	Final grammar update and check
Rev 2.2	20/10/2014	Added remark about assumption of power measurement in sensor nodes (Section 3.2.2)

1. INTRODUCTION

During the first year of the GreenDataNet project, Credit Suisse and EPFL have started the development of the Smart Monitoring System for green datacenters. The developed solution is composed by a software management tool and wireless sensor nodes.

The software management tool is the main user interface and brain of the system: it collects and processes all the data coming from the wireless sensor nodes, providing the required information to the user in terms of real-time/historical energy consumption, system alerts, and environmental conditions.

The wireless sensor devices are tiny hardware devices capable of measuring the power consumption of electrical equipment (such as servers, racks, PDUs, CRAC, etc.). They measure the power consumption using conductive current sensors that can be clamped on powering cables on the fly, thus avoiding the halting of servers in production. One of the most important features is that the sensor nodes are powered using energy harvesting technique, i.e. they collect power from the wire that they are sensing at that moment, avoiding batteries replacement. The sensor nodes are also equipped with other sensors which measure environmental properties important to be monitored in datacenter rooms, such as temperature, humidity, light and vibrations.

1.1. DOCUMENT OVERVIEW

The rest of the document is organized as follows. Section 2 introduces the main smart monitoring framework and concepts. Section 3 focuses on the wireless sensor network architecture and components. Section 4 discusses the software developed for the wireless network management. Finally, Section 5 presents the Power Monitor System and Management application.

2. GREENDATANET SMART MONITORING SYSTEM

Efficient management and administration of datacenters are increasing in importance and impact in companies and organizations. However, ensuring an effective and efficient management and operation of datacenters is nowadays a very complex and challenging task. IT and infrastructure managers have to maximize the datacenter utilization minimizing at the same time operating costs. The overall scenario gets even more challenging considering that they have also to deal with several stringent requirements and constraints, generated by heterogeneous and diverging technical aspects: customer requirements, infrastructure costs, electrical energy costs, physical space available, etc. Innovative Data Centre Infrastructure Management (DCIM) tools are thus needed.

Monitoring and management tools are clearly key for success. In current datacenters, for example, typically less than 14% of energy arrives at the computing racks: it has been indeed estimated that processing receives 9%, storage 3%, and routing a bit less than 2%. In addition, even this is largely discarded. In the end, less than 1% of the energy is converted to useful work at CPU level. Clearly, tools for accurately monitor and manage how the energy is distributed and spent over the datacenter are essential for maximizing efficiency and minimizing losses.

However, energy monitoring management tools are today considered too complex, too expensive, or too difficult to use to provide both IT and facility managers with useful feedback about their energy consumption. In addition, most tools today are proprietary and not flexible enough to deal with the heterogeneous environment represented by the modern datacenter ecosystem. The design and development of the GreenDataNet Smart Monitoring System have been thought to fulfill these needs. We have indeed developed innovative tools aimed at monitoring, analyzing and then optimizing the energy consumption in datacenters. The developed technology is a leap forward to today's DCIM since it is more efficient, flexible and easy-to-use.

The GreenDataNet main monitoring solution is composed by several parts. The environmental data (such as energy consumption, room temperature, humidity, etc.) are acquired by deploying a wireless sensor network (WSN). The WSN is composed by several wireless nodes equipped with several sensors. Every node transmits wirelessly the acquired data to its coordinator node. The main idea is to deploy a single WSN (i.e. one coordinator) per system room within a datacenter. The coordinator node is capable of coordinating the actions of all the sensor nodes in its network. The coordinator is plugged to a small data acquisition server, which is used to provide the user interface to the WSN administrator, as well as to log all the acquired data and communicate those to the main

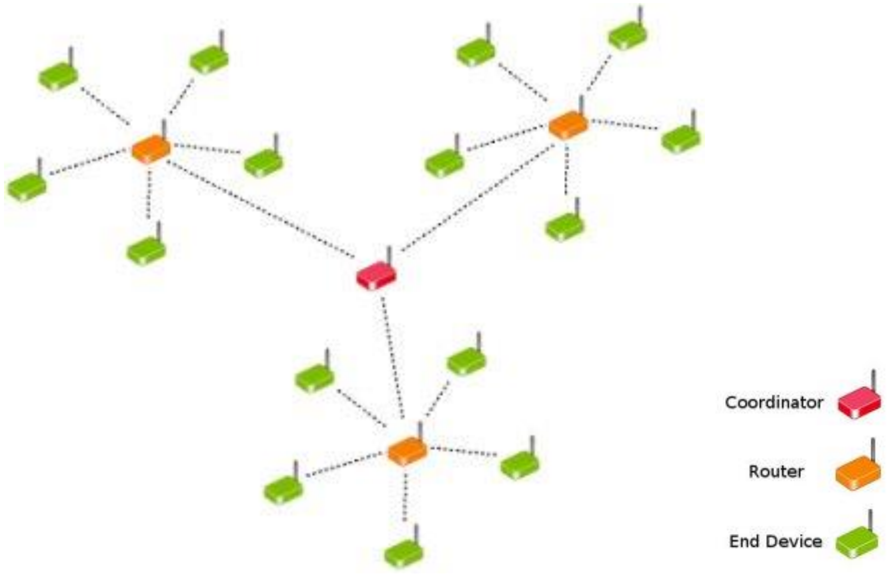
PMSM (i.e. Power Monitor System and Management) application. PMSM is the application used to collect all the data coming from the different WSNs deployed in the different system rooms or datacenters. The main user interface is also represented by the PMSM application, which provides information to the user in terms of real-time/historical energy consumption, system alerts, and environmental conditions.

The following sections will describe in details the features of each sub-component, namely the WSN concept, the wireless nodes, the coordinator, the data logger server and, finally the PMSM application.

3. WIRELESS SENSOR NETWORK ARCHITECTURE

The infrastructure used to measure the power consumption, as well as other parameters like temperature, humidity and people presence within rooms (via light sensors), is based on wireless sensor network technology.

A wireless sensor network (WSN) is a spatially distributed set of autonomous sensors used to monitor physical or environmental conditions and to cooperatively transmit the acquired data wirelessly through the network to a main location.



The main network protocol used in our WSN is based on the IEEE 802.15.4. Within the WSN there are mainly three types of wireless nodes (see the above figure):

1. The coordinator: is the "master" device, it governs the entire network. It is connected to a local data logger server.
2. The router: they route the information which is sent by the end-devices to the coordinator.
3. The sleep-end or end-device: they are the sensor nodes, the ones which take the information from the environment.

The main network is created as collection of several tree and star topologies. There are some basic rules:

- The end devices connect to a router or a coordinator.
- The routers can connect among them and with the coordinator.
- The coordinators cannot sleep.
- The routers and end-devices can go to sleep in order to save power.

Using a WSN represents a scalable monitoring solution, since adding new devices can be done on-the-fly and plug&play, and also flexible, since wireless sensor nodes can be easily moved, removed or added.

3.1 COORDINATOR AND DATA LOGGER

The room data logger is based on BeagleBone Black platform (see the picture on the side). Its main processor is a Texas Instruments AM335x, based on a 1GHz ARM® Cortex-A8. The platform provides 512MB DDR3 RAM, plus 2GB 8-bit eMMC on-board flash storage.

The main communication interfaces are:

- USB client for power & communications
- USB host
- Ethernet

- HDMI

The platform runs a full-fledge Ubuntu Operating System, as well as a light-weight web server. The main task of the room data logger is to run the WSN configuration and management software. The room data logger is, indeed, interfaced to the WSN coordinator node (in the bottom figure) via USB.

3.2 WIRELESS SENSOR NODES

The wireless nodes (i.e. coordinators, routers and end-devices) within the WSN are based on the same System-on-Chip platform, i.e. the NXP Jennic JN51X8 processor family. The core of the system is a 32-bit microcontroller with a 2.4 Ghz radio transceiver, IEEE 802.15.4 compatible.

3.2.1 THE ROUTER DEVICE

The router nodes are based on the Wispes W24TH node, which embeds a Jennic JN5148 module. The node can act as router or end-device.

The W24TH node is provided with a series of on-board sensors:

- Digital temperature sensor
    - Codification 14-bit
    - Resolution 0.01°C
    - Accuracy ±0.3°C

        - Operating range -40 to 125°C
    - Digital humidity sensor
        - Codification 12-bit
        - Resolution 0.04 %RH
        - Accuracy 2 %RH
        - Operation range 0 to 100RH
    - Digital ambient light sensor
        - Spectral response is approximately human eye response
        - Luminance to digital converter
        - Wide range and high resolution (0.23 – 100000 lx)
        - Small measurement variation (±15%)
    - Additional sensors:
        - External temperature analog probe
        - Mox gas sensor (VOC, O3, NOx, NH4, CO ...)
        - 3-axis accelerometer sensor

The W24TH node hosts also a 20-pin expansion connector for connecting optional expansion daughter boards. The router is moreover equipped with a microSD card reader for local storing, data logging and backup. The router node implements also a USB battery charger.

The node is highly optimized for ultra-low power consumption, i.e. only 8µA are used in sleep mode for extremely long battery life.

3.2.2 THE SLEEP-END DEVICE

The sleep-end devices are tiny hardware devices capable of measuring the power consumption of electrical equipment. They measure the power consumption using conductive current sensors that can be clamped on powering cables on the fly. It is important to mention that the measured power is assumed to be constant in current server models for relative large periods of time (in the order of hundreds of seconds), thus we assume the power factor in the measured interval is constant and the devices are able to acquire an accurate power measurement in a certain interval by only using measuring the current in that period.

However, if this situation changes in future server models (which is not expected as typically newer models are even more stable in input current requirements), the node could be modified to make it still applicable by measuring actual differential power between two points in the server, but at the expense of making its internal circuitry more complex and increase its power consumption. Thus, it will not be performed in the GreenDataNet project if not observed as strictly necessary.

These sensors are based on the Jennic JN5168 module, which embeds the same 32-bit microcontroller with a 2.4 GHz radio transceiver, like the routers.

The current measurement range is 0 – 32A, with a resolution of 40 mA.

The sleep-end node can provide current consumption information in terms of:

- RMS

- Peak-to-Peak
- Frequency

One of the most important features of this node is that the sleep-end device implements an energy harvester. The node can self-sustain its operations by harvesting energy from the monitored current. The batteries are used only as secondary power supply to guarantee a fast start-up of the system. The node harvests energy when the power consumed by the device under measurement is in the range 10W÷10kW, which also corresponds to the range of current 50mA÷50A drawn directly from the main. Moreover, the sleep-end node is highly optimized for ultra-low power consumption, i.e. only 4µA power consumption in sleep mode for extremely long battery life.

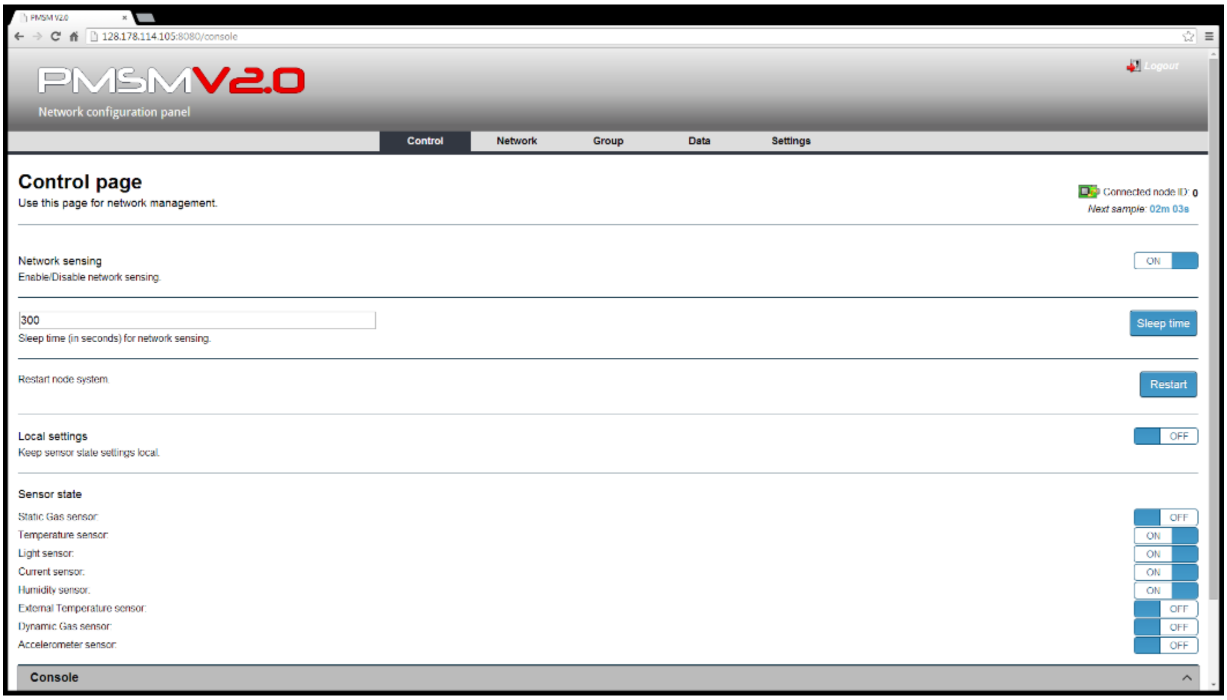
Compared to other products on the market, our sensor devices provide a much cheaper acquisition solution, reducing costs for hardware, cabling, installation and maintenance. The sensor nodes can be exploited to measure and monitor all the computing components in a datacenter, such as all the servers, the entire racks, the Power Distribution Unit, but also the not computing components, such as CRAC, the cooling infrastructures, lighting, etc.

4. WSN CONTROL PANEL

The data logger server runs a software application, called WSN Control Panel. The main objective of this application is twofold: providing the user interface for the WSN administration and management, as well as the first level of data logging at WSN level.

The WSN Control Panel application provides a web based interface, where system administrators can log in (also remotely) in order to control the WSN status. The application is mainly divided into several pages, which are accessible by the user via a tab at the top of the main page. We will describe more into details the main important ones.

4.1 CONTROL



The first entry is represented by the control tab. The main objective of this page is to give to the user the capability to control all the main characteristics and features of the WSN.

User can start or stop the data acquisition, set the acquisition sampling rate, as well as monitoring when the next samples will be acquired.

User can also configure the activation or deactivation of the several sensor types available on the wireless nodes. Moreover, the user can set the main network parameters, like PAN ID, channel number, etc.

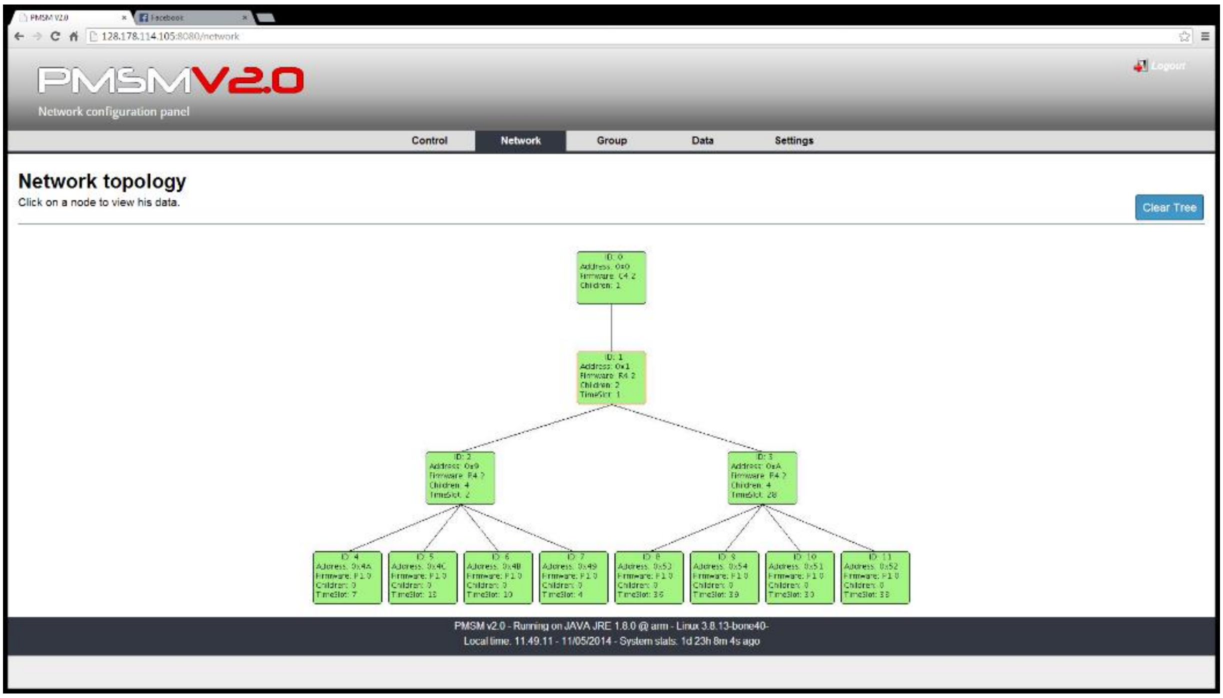
User can also use this page to remotely control the wireless nodes, i.e. the user can connect to any other nodes within the network just specifying its network address, and then the page will show the node parameters of the target node, giving to the user the capability of modify those.

The firmware update button represents the last important feature of this page. User can use this feature to enable the firmware update over the air for all the nodes within the network. It is also possible to have the firmware upload only for single specific nodes or groups of nodes.

Finally, this page can display a command line terminal, which prints out the data streams coming from the sensor nodes.

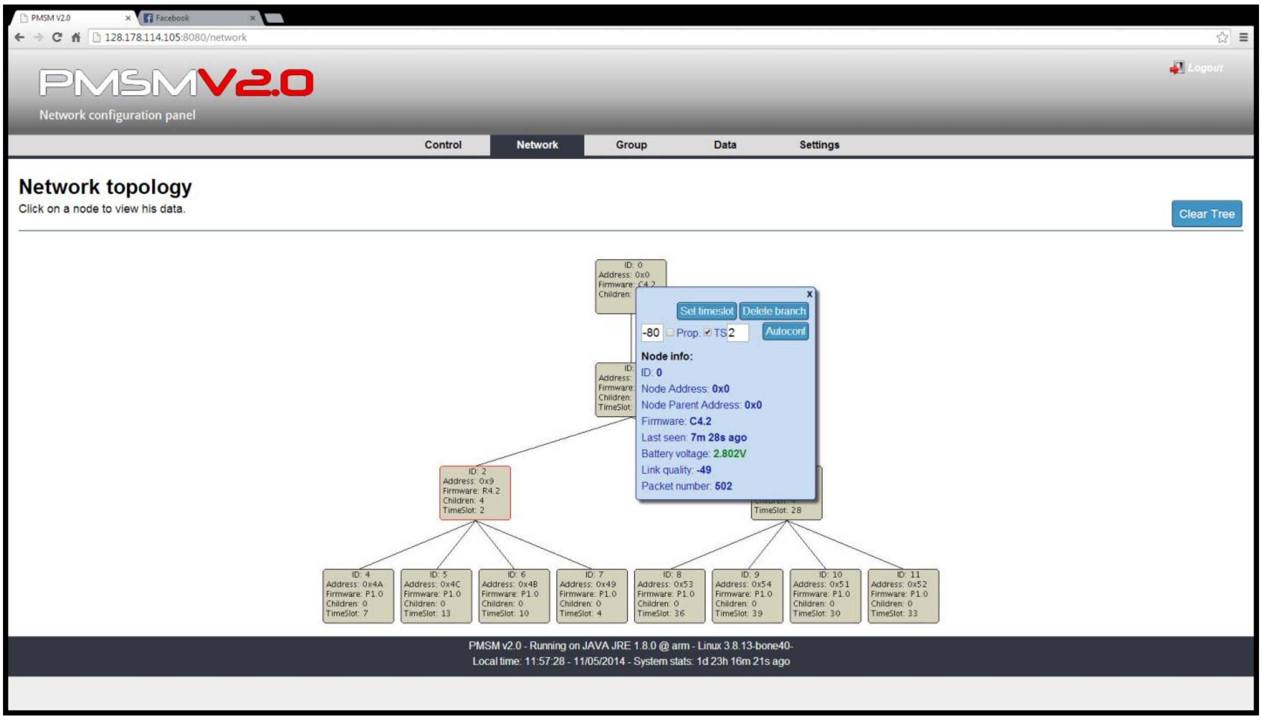
4.2 NETWORK

The network tab is mainly used to give to the user a graphical overview of the WSN topology.



This page shows also the main nodes information, like the node ID, the node network address, the node firmware version, and its transmission timeslot. The color of the node is associated to its state, as well as its battery state.

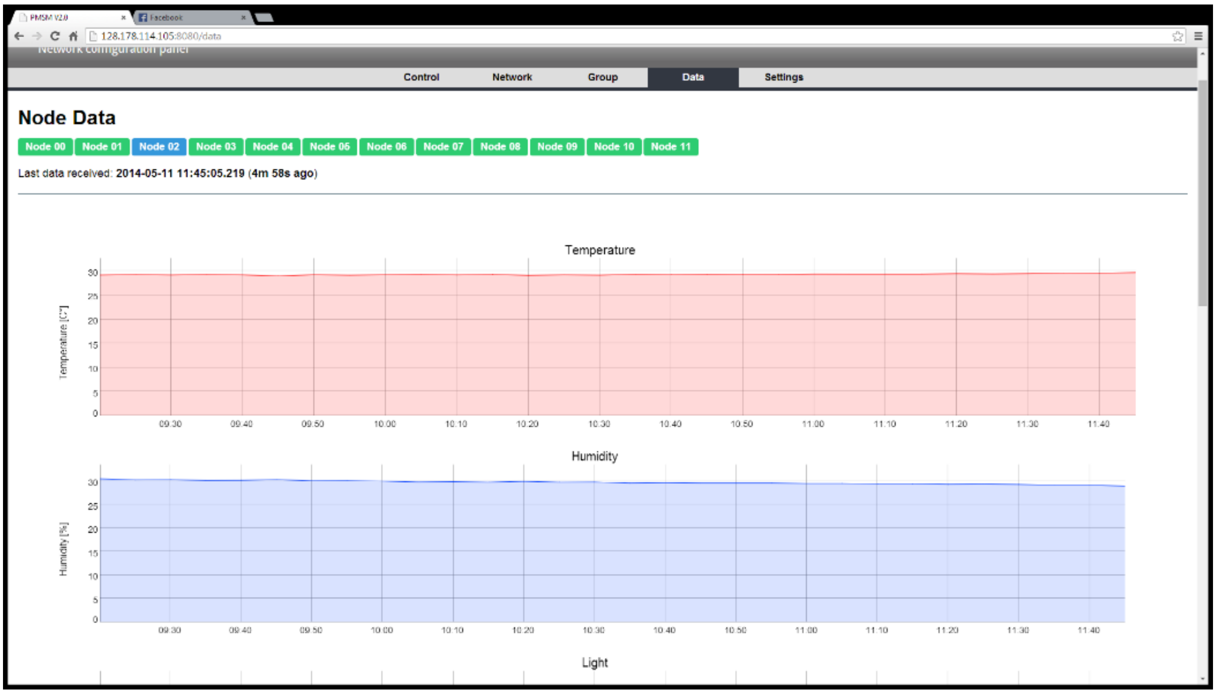
The same network page can be used for automated network installation and management.



This feature enables a very easy and intuitive network creation with just very few user clicks. The same functionality can be used for modifying the network topology, like removing or moving nodes or entire network branches.

4.3 DATA

The data tab is used to show the acquired data by the sensor nodes. The page will display several graphs, one for each sensor host by the target node. User can switch to a different node just clicking on the right button on the top.



5. PMSM: POWER MONITOR SYSTEM AND MANAGEMENT

The monitoring system is also equipped with a user-friendly interface, called PMSM - Power Monitor System and Management, providing the required information to datacenter facility and IT managers in terms of real-time/historical energy consumption and system alerts.

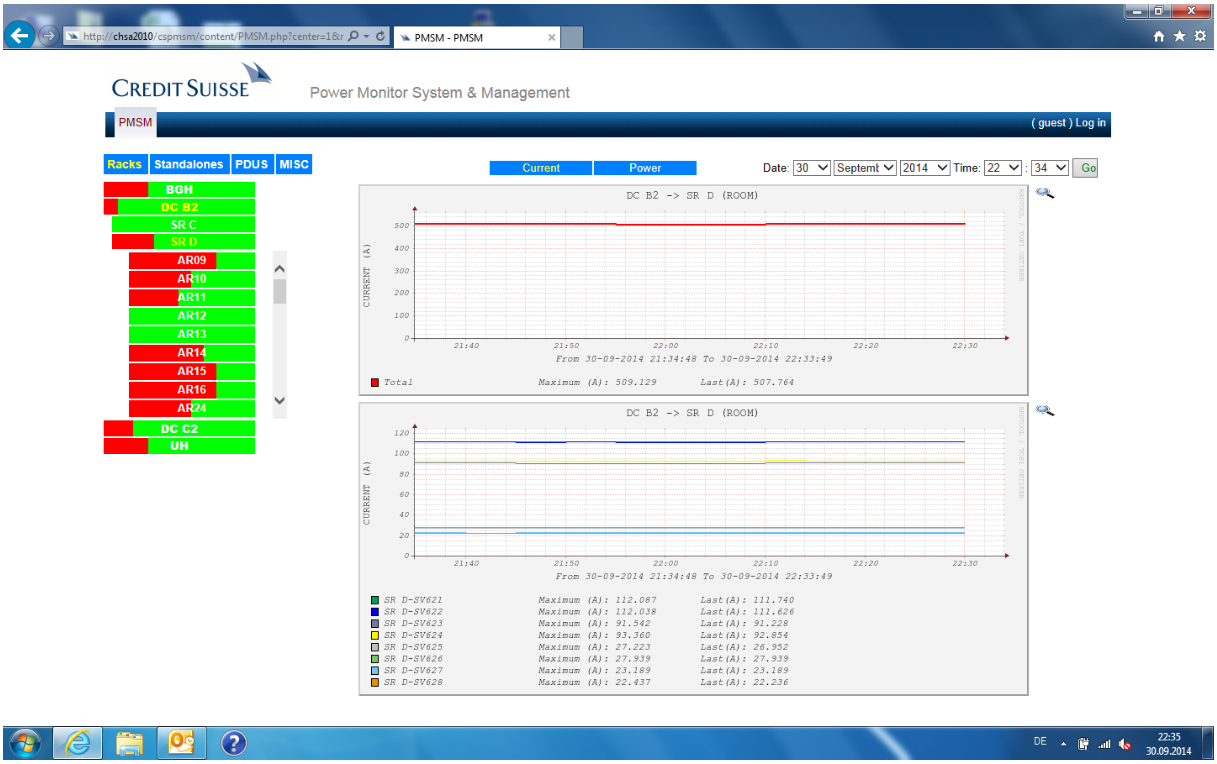
This software management tool is the main brain of the system, since it collects and processes all the acquired data from the several WSNs deployed within the datacenter (i.e. within the several system rooms) or in different datacenters.

The main PMSM interface is composed by different parts (please refer to the next figure):

- User can choose to display consumption data focusing of different types of components, like rack, PDU, standalone units, or other equipment (i.e. networking, disks, etc), just selecting the right button on the left-top menu,
- The list on the left gives a graphical overview of the datacenters under monitoring. Every line represent a datacenter. After selecting a datacenter in the list, its system rooms will be

displayed. Selecting a system room, the list will show the equipment within the room. The color of the bar gives a visual feedback about the level of energy currently consumed.

- The central part of the window is used for displaying graphs about consumption. User can select to display current or power consumption graphs.



The PMSM is also capable to generate reports, as well as displaying historical data graphs. User can configure alerts and warnings, PMSM will notify the system administrator (i.e. visually or via emails) in the case those conditions are verified. Datacenter administrator can easily configure the PMSM software just uploading a CSV file describing the datacenter infrastructure (i.e. rooms, equipment location, equipment type, monitoring mapping).

6. CONCLUSION

In this deliverable 2.1 (D2.1) we have summarized the work developed in the first year of GreenDataNet between Credit Suisse and EPFL for the development of a new generation of smart monitoring infrastructure for next generation of green datacenters. The developed solution is composed by a multi-hop configurable network topology of self-power wireless sensor nodes and a complete software management tool.

The first version of the software management tool (PMSM) includes a main user interface and provides a complete framework to collect and analyze all the data coming from the wireless sensor nodes. It is able to provide detailed information to the user in terms of real-time and historical energy consumption, system alerts, and environmental conditions analysis.

On the other hand, the wireless sensor devices developed in this first version of the system are very small hardware devices capable of measuring the power consumption of electrical equipment (such as servers, racks, PDUs, CRAC, etc.). Their main measurement includes power consumption using conductive current sensors that can be clamped on powering cables on the fly (i.e., with minimal installation) thus avoiding the halting of servers in production. One of the key features of the proposed generation of sensor nodes is that they are self-powered using an energy harvesting technique that retrieves the necessary power for them to operate from the wire that are sensing. Moreover, this extracted power is able to make these first generation of nodes include other sensors which measure environmental properties that are important for datacenter rooms (i.e., temperature, humidity, light and vibrations of servers and racks). Therefore, this D2.1 proves the possibility to provide quasi-eternal self-power monitoring networks of sensors with no overhead in the datacenter power operation efficiency. Moreover, in the next generation of PMSM (to be developed for the end of GreenDataNet, in the next two years) we will target to refine this initial design and improve significantly the energy efficiency of this first generation of nodes, as well as expanding the functionality of the software monitoring framework of PMSM by developing energy prediction estimates of the complete datacenter room.

This solution may be a nice alternative to the IT driven approach developed by Eaton in deliverable D1.5 “Software Architecture Specification” in the case of data centres where operators do not want to, nor allow, the use of such monitoring within the IT production network. In other data centres both solutions would complete each other ideally to provide detailed information for the whole data centre infrastructure.